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**Vol. XVII, Part VI**

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### Original Articles

# ORIGINAL ARTICLES

## VARIATIONS IN THE PROPERTIES OF THE COTTON FIBRE IN RELATION TO ITS POSITION ON THE SURFACE OF THE SEED II

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(Received for publication on 18 February 1947)

(With nine text figures)

THE problem of the variation in fibre properties on the surface of the seed of a number of standard Indian cottons has been dealt with in an earlier publication [Koshal and Ahmad, 1932] in which the results of an investigation relating to fibre-length, fibre-weight per inch and fibre-strength were described in detail. The present paper contains an account of a similar investigation with respect to three other remaining properties, namely, fibre-rigidity, ribbon-width and convolutions per inch, using the same standard Indian cottons.

### Material

The material used in this investigation was the same as that on which tests were made by Koshal and Ahmad [1932], the slivers having been prepared conjointly by us.

Only in the case of Nandyal 14 fibres from all the four regions of the seed (base, apex, right flank, left flank) and the combed fibres were tested, while in the case of the other cottons the fibres from the basal and the apical regions were examined.

### Methods

The methods adopted in the determination of the above properties are the same as have been described by Ahmad [1933]. It should, however, be made clear that for each cotton the same set of fibres were used in successive determinations of the three properties. (The method of determining fibre-rigidity is especially dealt with in the Appendix.) The statistical methods applied were similar to those employed by Koshal and Ahmad [1932].

### Discussion of Results

#### (Fibre rigidity)

(*a*) *Base and Apex.*

The frequency distributions for fibre-rigidity for the fibres taken from the basal and the apical regions of the seeds of eight Indian cottons are shown in Table I.

Table I

*Frequency distribution—fibre rigidity, base and apex*

| Dynes Cm.$^2$ $10^{-2}$ | Nandyal 14 | | P. A. 4F. | | C. A. 9 (1928-29) | | C. A. 9 (1929-30) | | Gadag 1 (1928-29) | | Gadag 1 (1927-28) | | Verum 262 (Nagpur) | | Surat 1027 A. L. F. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group | B | A | B | A | B | A | B | A | B | A | B | A | B | A | B | A |
| 0 . . | 18 | 6 | 36 | 5 | 6 | 1 | 15 | 1 | 18 | 2 | 19 | 0 | 15 | 0 | 40 | 3 |
| 1 . . | 28 | 11 | 42 | 7 | 24 | 5 | 28 | 10 | 61 | 6 | 53 | 13 | 30 | 5 | 34 | 11 |
| 2 . . | 25 | 10 | 32 | 14 | 34 | 22 | 34 | 23 | 30 | 24 | 41 | 6 | 20 | 5 | 18 | 18 |
| 3 . . | 21 | 29 | 22 | 19 | 32 | 28 | 25 | 41 | 16 | 25 | 17 | 21 | 19 | 8 | 14 | 26 |



A

TABLE I

*Frequency distribution=fibre rigidity, base and apex*

| Dynes Cm.² 10² | Nadyal 14 | | P. A. 4F, | | C. A. 9 (1928-29) | | C. A. 9 (1929-30) | | Gadag 1 (1928-29) | | Gadag 1 (1927-28) | | Verum 262 (Nagpur) | | Surat 1027 A. L. F. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group | B | A | B | A | B | A | B | A | B | A | B | A | B | A | B | A |
| 4 . . | 19 | 26 | 11 | 27 | 19 | 33 | 22 | 30 | 10 | 26 | 14 | 19 | 18 | 10 | 8 | 15 |
| 5 . . | 10 | 20 | 6 | 19 | 13 | 19 | 18 | 17 | 10 | 14 | 6 | 17 | 8 | 19 | 9 | 13 |
| 6 . . | 16 | 12 | 2 | 22 | 12 | 20 | 1 | 13 | 0 | 20 | 1 | 17 | 10 | 18 | 5 | 8 |
| 7 . . | 5 | 12 | 2 | 12 | 5 | 4 | 4 | 9 | 1 | 15 | 1 | 18 | 8 | 16 | 6 | 7 |
| 8 . . | 2 | 7 | 0 | 7 | 2 | 7 | 1 | 4 | 2 | 10 | 1 | 15 | 5 | 14 | 2 | 11 |
| 9 . . | 1 | 4 | 1 | 9 | 2 | 3 | 1 | 1 | 0 | 4 | | 10 | 5 | 10 | 3 | 8 |
| 10 . . | 1 | 5 | 1 | 4 | 1 | 3 | 0 | 1 | 1 | 5 | | 6 | 2 | 8 | 4 | 6 |
| 11 . . | 1 | 2 | | 0 | | 1 | 0 | | 0 | 2 | | 2 | 1 | 5 | 3 | 1 |
| 12 . . | 0 | 1 | | 2 | | 0 | 1 | | 1 | 0 | | 2 | 5 | 7 | 1 | 4 |
| 13 . . | 0 | | | 3 | | 3 | | | | 2 | | 2 | 3 | 3 | 2 | 6 |
| 14 . . | 1 | | | | | | | | | | | 1 | 0 | 3 | 0 | 1 |
| 15 . . | | | | | | | | | | | | | 0 | 3 | 0 | 2 |
| 16 . . | | | | | | | | | | | | | 2 | 1 | 0 | 2 |
| 17 . . | | | | | | | | | | | | | 0 | 2 | 0 | 0 |
| 18 . . | | | | | | | | | | | | | 0 | 5 | 0 | 0 |
| 19 . . | | | | | | | | | | | | | 0 | 0 | 0 | 1 |
| 20 . . | | | | | | | | | | | | | 0 | 2 | 1 | 1 |
| 21 . . | | | | | | | | | | | | | 1 | 1 | | 0 |
| 22 . . | | | | | | | | | | | | | | 3 | | 2 |
| 23 . . | | | | | | | | | | | | | | 1 | | 1 |
| 24 . . | | | | | | | | | | | | | | 0 | | 1 |
| 25 . . | | | | | | | | | | | | | | 1 | | 0 |
| 26 . . | | | | | | | | | | | | | | 3 | | 0 |
| 27 . . | | | | | | | | | | | | | | | | 0 |
| 28 . . | | | | | | | | | | | | | | | | 1 |
| 29 . . | | | | | | | | | | | | | | | | 1 |
| 30 . . | | | | | | | | | | | | | | | | 1 |
| Total No. of tests | 148 | 154 | 155 | 150 | 150 | 149 | 150 | 150 | 150 | 153 | 153 | 149 | 152 | 153 | 150 | 151 |

B=Base; A=Apex

The mean values and all the statistical constants calculated from these distributions are given in Table II.

# TABLE II

*Frequency constants for frequency distributions of fibre rigidity—base and apex*

| No. | Cotton | Region | Mean M | $\frac{A-B}{B} \times 100$ | .. | Cv | $Q_1$ | $Q_3$ | $e_1$ | $e_2$ | $\frac{Q_3-Q_1}{2}$ =Q | E (S. O.) | $\frac{e_1-e_2}{M}$ C. A. | Ed | $\frac{\text{M-Mode}}{..}$ =Skewness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 1 | Nandyal 14 | Base | 3·11 | 42·2 | 2·44 | 78·3 | 1·19 | 4·55 | 1·92 | 1·44 | 1·68 | 1·64 | 0·154 | 56·8 | 0·513 |
| | | Apex | 4·42 | | 2·55 | 57·6 | 2·63 | 5·92 | 1·79 | 1·50 | 1·64 | 1·72 | 0·064 | | 0·528 |
| 2 | P. A. 4F | Base | 1·97 | 156·8 | 1·75 | 88·4 | 0·61 | 2·83 | 1·36 | 0·86 | 1·11 | 1·18 | 0·252 | 110·4 | 0·748 |
| | | Apex | 5·06 | | 2·74 | 54·0 | 3·15 | 6·52 | 1·91 | 1·46 | 1·69 | 1·84 | 0·088 | | 0·390 |
| 3 | C. A. 9 (1928-29) | Base | 3·26 | 39·6 | 2·00 | 61·4 | 1·77 | 4·42 | 1·49 | 1·16 | 1·32 | 1·35 | 0·100 | 53·8 | 0·546 |
| | | Apex | 4·55 | | 2·40 | 52·7 | 2·88 | 5·74 | 1·67 | 1·18 | 1·43 | 1·62 | 0·108 | | 0·555 |
| 4 | C. A. 9 (1929-30) | Base | 2·82 | 38·0 | 1·94 | 68·9 | 1·35 | 4·03 | 1·46 | 1·21 | 1·34 | 1·31 | 0·090 | 60·0 | 0·504 |
| | | Apex | 3·89 | | 1·55 | 39·7 | 2·64 | 4·99 | 1·26 | 1·10 | 1·18 | 1·04 | 0·040 | | 0·647 |
| 5 | Gadag 1 (1928-29) | Base | 2·00 | 138·5 | 1·87 | 93·6 | 0·97 | 2·77 | 1·18 | 0·77 | 0·97 | 1·26 | 0·205 | 104·6 | 0·772 |
| | | Apex | 4·77 | | 2·32 | 48·9 | 2·80 | 6·44 | 1·97 | 1·67 | 1·81 | 1·57 | 0·064 | | 0·604 |
| 6 | Gadag 1 (1927-28) | Base | 1·99 | 183·4 | 1·44 | 72·4 | 0·91 | 2·65 | 1·08 | 0·66 | 0·87 | 0·97 | 0·208 | 122·2 | 0·687 |
| | | Apex | 5·64 | | 2·87 | 50·8 | 3·42 | 7·60 | 2·22 | 1·96 | 2·09 | 1·93 | 0·046 | | 0·187 |
| 7 | Verum 262 | Base | 4·17 | 110·3 | 3·78 | 90·6 | 1·32 | 5·95 | 2·85 | 1·78 | 2·32 | 2·55 | 0·257 | 99·0 | 0·249 |
| | | Apex | 8·77 | | 5·57 | 63·5 | 5·09 | 10·90 | 3·68 | 2·13 | 2·91 | 3·76 | 0·177 | | 0·808 |
| 8 | Surat 1027 A. L. F. | Base | 3·00 | 122·0 | 3·43 | 114·4 | 0·49 | 4·36 | 2·52 | 1·36 | 1·94 | 2·32 | 0·385 | 83·0 | * |
| | | Apex | 6·66 | | 6·14 | 92·3 | 2·77 | 8·71 | 3·89 | 2·05 | 2·97 | 4·14 | 0·276 | | 0·935 |

.. = Standard Deviation
Cv = Coefficient of Variation
B = Base
A = Apex

$Q_1$ = Lower Quartile
$Q_3$ = Upper Quartile
Q = Semi Inter-Quartile Range
E = Probable Error of (S. O.) single observation
Ed = Total percentage divergence between Base and Apex
* = Skewness not calculable

$e_1$ = Distance of mean from $Q_1$
$e_2$ = Distance of mean from $Q_3$
$\frac{e_1-e_2}{M}$ = Coefficient of Asymmetry = C. A.

The mean values and their differences which are given in columns 4 and 5 of Table II, may be considered first. It is found that in the case of all cottons the apical fibres possess higher rigidity than the basal fibres; the differences in the mean values, calculated in terms of the basal fibres are, however, not the same for the different cottons, but vary from 38·0 per cent for C. A. 9 (1929-30) to 183·4 per cent for Gadag 1 (1927-28), showing a great dissimilarity of behaviour in this respect by the different cottons. These differences are all in the same direction, and are, on the whole, large; but, before we may draw any conclusions from them, it is necessary to apply some criteria of significance. The need for applying some such criteria becomes evident when we consider the values of coefficient of variation for this property given in column 7 of Table II. It will be seen that this statistic varies from 39·7 to 114·4, showing the extreme dispersion in this property from fibre to fibre in the same sample. Now, in a normal distribution the standard error test would be adequate, but an inspection of Table I would show that the values obtained for this property are very asymmetrically distributed, which is also evident from the disparity in the values of $e_1$, $e_2$, Q and E (S. O.). Hence in the present case the standard error test cannot be applied and it is proposed to apply the following criteria.

In the first place it will be noticed that, for all cottons, except Nandyal 14 and C. A. 9 (1929-30), the mean value for the apical fibres is greater than the upper quartile for the basal fibres. Even in the case of these two exceptions the upper quartile for the basal fibres is very nearly equal to the mean for the apical fibres, showing clearly that there is a predominance of fibres of greater rigidity in the apical region of the seed and of fibres of lower rigidity in the basal region.

In order to judge the results more rigorously, we can apply a test known as percentage divergence test. For this purpose the frequencies are calculated on percentage basis for the different groups; the difference between the basal and the apical values for each individual group is shown in Table III.

TABLE III

*Percentage frequency distribution of fibre rigidity, and divergence percentage*

| Dynes cm.$_2$ 10-$_3$ Group | Nandyal 14 | | | P. A. 4F. | | | C. A. 9 (1928-29) | | | C. A. 9 (1929-30) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B | A | A-B | B | A | A-B | B | A | A-B | B | A | A-B |
| 0 . . . . | 12·2 | 3·9 | —8·3 | 23·2 | 3·3 | —19·9 | 4·0 | 0·7 | —3·3 | 10·0 | 0·7 | —9·3 |
| 1 . . . . | 18·9 | 7·1 | —11·8 | 27·1 | 4·7 | —22·4 | 16·0 | 3·4 | —12·6 | 18·6 | 6·7 | —11·9 |
| 2 . . . . | 16·9 | 12·3 | —4·6 | 20·7 | 9·3 | —11·4 | 22·7 | 14·8 | —7·9 | 22·6 | 15·3 | —7·3 |
| 3 . . . . | 14·2 | 18·9 | 4·7 | 14·2 | 12·7 | —1·5 | 21·3 | 18·8 | —2·5 | 16·7 | 27·3 | 10·6 |
| 4 . . . . | 12·8 | 16·9 | 4·1 | 7·1 | 18·0 | 10·9 | 12·7 | 22·1 | 9·4 | 14·6 | 20·0 | 5·4 |
| 5 . . . . | 6·8 | 13·0 | 6·2 | 3·9 | 12·7 | 8·8 | 8·7 | 12·7 | 4·0 | 12·0 | 11·2 | —0·8 |
| 6 . . . . | 10·8 | 7·8 | —3·0 | 1·3 | 14·7 | 13·4 | 8·0 | 13·4 | 5·4 | 0·7 | 8·7 | 8·0 |
| 7 . . . . | 3·3 | 7·8 | 4·5 | 1·3 | 8·0 | 6·7 | 3·3 | 2·7 | —0·6 | 2·7 | 6·0 | 3·3 |
| 8 . . . . | 1·3 | 4·5 | 3·2 | 0·0 | 4·7 | 4·7 | 1·3 | 4·7 | 3·4 | 0·7 | 2·7 | 2·0 |
| 9 . . . . | 0·7 | 2·6 | 1·9 | 0·6 | 6·0 | 5·4 | 1·3 | 2·0 | 0·7 | 0·7 | 0·7 | 0·0 |
| 10 . . . . | 0·7 | 3·3 | 2·6 | 0·6 | 2·6 | 2·0 | 0·7 | 2·0 | 1·3 | 0·0 | 0·7 | 0·7 |
| 11 . . . . | 0·7 | 1·3 | 0·6 | 0·0 | 0·0 | 0·0 | 0·0 | 0·7 | 0·7 | 0·0 | 0·0 | 0·0 |
| 12 . . . . | 0·0 | 0·6 | 0·6 | 0·0 | 1·3 | 1·3 | 0·0 | 0·0 | 0·0 | 0·7 | 0·0 | —0·7 |
| 13 . . . . | 0·0 | 0·0 | 0·0 | 0·0 | 2·0 | 2·0 | 0·0 | 2·0 | 2·0 | | | |
| 14 . . . . | 0·7 | 0·0 | —0·7 | | | | | | | | | |
| 15 . . . . | | | | | | | | | | | | |
| 16 . . . . | | | | | | | | | | | | |
| 17 . . . . | | | | | | | | | | | | |

TABLE III

*Percentage frequency distribution of fibre rigidity and divergence percentage*

| Dynes cm² 01-2 | Nandyal 14 | | | P. A. 4F. | | | C. A. 9 (1928-29) | | | C. A. 9 (1929-30) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group | B | A | A-B | B | A | A-B | B | A | A-B | B | A | A-B |
| 18 | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | |
| above 22 | | | | | | | | | | | | |
| Divergence : | | | 56·8 | | | 110·4 | | | 53·8 | | | 60·0 |

B = Base ; A = Apex

| Gadag 1 (1928-29) | | | Gadag 1 (1927-28) | | | Verum 262 | | | 1027 A. L. F. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| B | A | A-B | B | A | A-B | B | A | A-B | B | A | A-B |
| 12·0 | 1·3 | —10·7 | 12·4 | 0 | —12·4 | 9·9 | 0 | —9·9 | 26·6 | 2·0 | —24·6 |
| 40·6 | 3·9 | —36·7 | 34·6 | 8·7 | —25·9 | 19·7 | 3·3 | —16·4 | 22·7 | 7·2 | —15·5 |
| 20·0 | 15·8 | —4·2 | 26·8 | 4·0 | —22·8 | 13·2 | 3·3 | —9·9 | 12·0 | 11·9 | —0·1 |
| 10·6 | 16·3 | 5·7 | 11·0 | 14·2 | 3·2 | 12·5 | 5·2 | —7·3 | 9·4 | 17·2 | 7·8 |
| 6·7 | 17·0 | 10·3 | 9·2 | 12·8 | 3·6 | 11·8 | 6·5 | —5·3 | 5·3 | 10·0 | 4·7 |
| 6·7 | 9·1 | 2·4 | 3·9 | 11·4 | 7·5 | 5·2 | 12·4 | 7·2 | 6·0 | 8·6 | 2·6 |
| 0·0 | 13·1 | 13·1 | 0·7 | 11·4 | 10·7 | 6·6 | 11·9 | 5·3 | 3·3 | 5·3 | 2·0 |
| 0·7 | 9·8 | 9·1 | 0·7 | 12·1 | 11·4 | 5·2 | 10·5 | 5·3 | 4·0 | 4·6 | 0·6 |
| 1·3 | 6·5 | 5·2 | 0·7 | 10·1 | 9·4 | 3·3 | 9·1 | 5·8 | 1·3 | 7·2 | 5·9 |
| 0·0 | 2·6 | 2·6 | 0·0 | 6·7 | 6·7 | 3·3 | 6·5 | 3·2 | 2·0 | 5·3 | 3·3 |
| 0·7 | 2·0 | 1·3 | 0·0 | 4·0 | 4·0 | 1·3 | 5·2 | 3·9 | 2·7 | 4·0 | 1·3 |
| 0·0 | 1·3 | 1·3 | 0·0 | 1·3 | 1·3 | 0·7 | 3·3 | 2·6 | 2·0 | 0·7 | —1·3 |
| 0·7 | 0·0 | —0·7 | 0·0 | 1·3 | 1·3 | 3·3 | 4·6 | 1·3 | 0·7 | 2·7 | 2·0 |
| 0·0 | 1·3 | 1·3 | 0·0 | 1·3 | 1·3 | 2·0 | 1·9 | —0·1 | 1·3 | 4·0 | 2·7 |
| | | | 0·0 | 0·7 | 0·7 | 0·0 | 1·9 | 1·9 | 0·0 | 0·7 | 0·7 |
| | | | | | | 0·0 | 1·9 | 1·9 | 0·0 | 1·3 | 1·3 |
| | | | | | | 1·3 | 0·7 | —0·6 | 0·0 | 1·3 | 1·3 |
| | | | | | | 0·0 | 1·3 | 1·3 | 0·0 | 0·0 | 0·0 |
| | | | | | | 0·0 | 3·3 | 3·3 | 0·0 | 0·0 | 0·0 |
| | | | | | | 0·0 | 0·0 | 0·0 | 0·0 | 0·7 | 0·7 |
| | | | | | | 0·0 | 1·3 | 1·3 | 0·7 | 0·7 | 0·0 |
| | | | | | | 0·7 | 0·7 | 0·0 | 0·0 | 0·0 | 0·0 |
| | | | | | | 0·0 | 5·2 | 5·2 | 0·0 | 4·6 | 4·6 |
| | | 104·6 | | | 122·2 | | | 99·0 | | | 83·0 |

The individual divergences added up (irrespective of sign) give the total percentage divergence between the values for the two regions of the seed. If in a given case, the difference for the two regions of the seed is not significant, then not only would the total divergence be small, but the individual values of divergence would be nearly alternately positive and negative. It will be seen from Table III that this is not the case for any one of the cottons. In almost every case the divergences

are negative in the first three or four groups and positive in the remaining groups and the total divergence is high, ranging from 53·8 to 122·2. Considering the case of Nandyal 14, for which the quartile test was inconclusive, the divergence is negative in the first three groups and, except for the 6th and the 14th, positive in all the other groups. The total divergence is also high, being 56·8. Similarly, in the case of C. A. 9 (1928-29), the total divergence is 53·8, the first four groups are negative and except for the seventh group all others are positive. For the same cotton of the following season the total divergence is 60·0, the first three groups are negative and, excepting the fifth, and the twelfth groups, all the others are positive. This analysis shows that even for these cottons the differences in mean values are significant, although they are small as compared with the others, which therefore must be highly significant.

We are thus led to conclude that fibres on the apical region of the seed possess higher fibre-rigidity than those on the basal region, the difference between the mean values for the two regions, varying from cotton to cotton.

The frequency distribution curves for the basal and the apical fibres for all the eight cottons are given in Fig. 1.

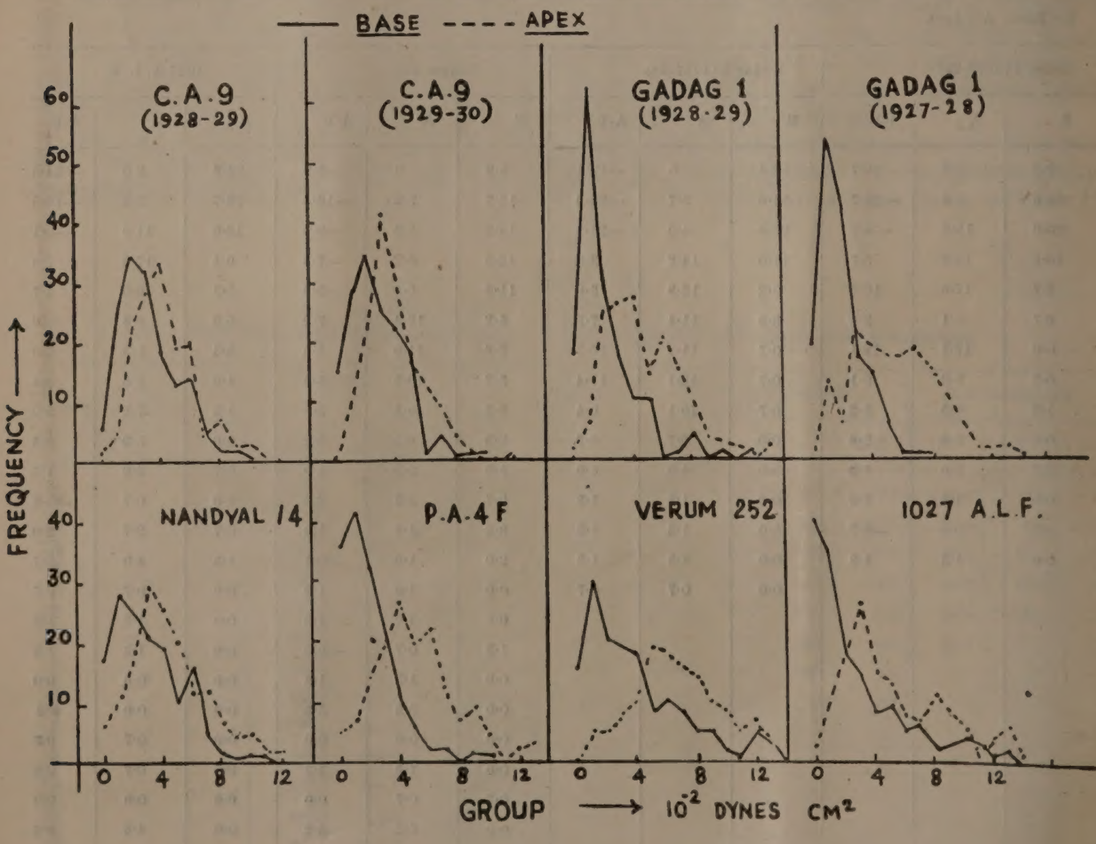


Fig. 1.

It is seen from these that all the curves deviate from the normal. This observation is supported by the high coefficient of asymmetry found for both the apical and the basal fibres, which are given in column 14 of Table II.

Comparing the curves for the apical and the basal fibres it is noticed that the distribution in the former is skew, while it shows a distinct tendency to J-shape in the latter. The comparatively lower values of the coefficient of asymmetry for the apical distributions (except for C. A. 9—1928-29, where it is nearly equal), as well as the lower values of the coefficient of variation for the apical fibres, afford statistical evidence for the greater departure from normality for the basal distributions.

A visual inspection of these curves shows that the cottons may be classified as follows under three heads in respect of the type of frequency distribution of rigidity values for the basal fibres.

Surat 1027 A. L. F. . . . . . . . . . . . Pronounced J-shape.
Nandyal 14, P. A. 4F, Gadag 1 and Verum 262 . . . . J-shape.
C. A. 9 . . . . . . . . . . . . . Least J-shape.

It is interesting to observe that a similar classification would result if the coefficient of variation were taken into consideration, 1027 A. L. F. having the maximum value and C. A. 9 (1928-29) the minimum value.

The cottons may also be classified in respect of the skewness of the curves for the apical fibres.

The skewness($s$) is to be expressed according to Pearson's formula, $s=\frac{\text{mean-mode}}{\text{standard deviation}}$. The result is as follows:

Verum 262 & 1027 A. L. F.: . . . . . Largely skew (skewness 70·>50).

Nandyal 14, P. A. 4F, C. A. 9, Gadag 1 (1928-29): . Skew (skewness between 0·250 and 0·750)

Gadag 1 (1927-28): . . . . . . . . Less skew (skewness <0·250)

Two different types of distribution are thus obtained for the same cotton, depending upon the region of the seed surface, the basal region giving a J-distribution and the apical region a skew distribution. This holds good more or less for all the eight cottons tested in this investigation.

We will now compare the mean values and the types of distribution for the different regions of the seed surface, with those obtained for the bulk sample and consider the effect of the former upon the latter. The values for the bulk samples are taken from *Technological Reports on Standard Indian Cottons* [Ahmad, 1931]:

TABLE IV

*Comparative fibre-rigidity values (dynes cm$^2$ $10^{-2}$.)*

| Cotton | Base | Apex | Bulk |
|---|---|---|---|
| Nandyal 14 | 3·11 | 4·42 | 3·03 |
| P. A. 4F | 1·97 | 5·06 | 3·85 |
| C. A. 9 (1928-29) | 3·26 | 4·55 | 4·28 |
| C. A. 9 (1929-30) | 2·82 | 3·89 | 5·31 |
| Gadag 1 (1928-29) | 2·00 | 4·77 | 2·47 |
| Gadag 1 (1927-28) | 1·99 | 5·64 | 2·72 |
| Verum 262 | 4·17 | 8·77 | 3·46 |
| 1027 A. L. F. | 3·00 | 6·66 | 2·25 |

It is found there from that in the case of five cottons out of eight the mean value for the bulk lies nearer to that for the basal than for the apical fibres. Among the remaining three cases it lies midway between the two for P. A. 4F, and nearer to the apical value for C. A. 9 (1928-29), while it is higher than the values either for the basal or the apical fibres for the same cotton of the following season. Thus for a majority of the cottons the bulk mean value lies nearer to that for the basal than for the apical fibres.

In so far as the distribution of these values is concerned, it has been shown by Koshal and Turner [1930] that when a sufficiently large number of fibres of 1027 A.L.F. were tested, the bulk sample yielded a characteristically J-shaped curve of distribution for fibre rigidity. For this cotton at least, therefore, the bulk sample is similar in this respect to the basal fibres. If this were true of other cottons as well, the effect of the apical fibres on a bulk sample, either in increasing the mean value by virtue of their higher rigidity or in modifying the distribution by virtue of their skewness, is masked to a large extent by the numerical preponderance of the less rigid fibres and the strong J-tendency in their distribution. A J-shaped distribution indicates the existence of a large number of fibres of low rigidity and a comparatively small number of high rigidity; the former possibly being included among the combed hairs, which will be discussed later, and the latter among the apical fibres.

*Seasonal fluctuations.* Only two cottons, Gadag 1 and C. A. 9 were tested for two different seasons. From the results obtained it is interesting to note that while the regional difference in the mean values between the basal and the apical fibres varies considerably from cotton to cotton as noted earlier, for any one cotton, from season to season, the variation is much narrower. For Gadag 1 the difference is 138·5 per cent in one season and 183·4 per cent in the other, and for C. A. 9 it is 38·0 per cent in one season and 39·6 per cent in the other. It is thus found that while the ratio between the values for the basal and the apical fibres varies considerably from cotton to cotton grown in the same season, for any one cotton grown in different season, the ratio is somewhat constant. This shows that the influence of environmental factors on the relative variation in the rigidity of the fibres from different parts of the seed is fairly constant. Further, the types of frequency distributions are also nearly the same both for the apical and the basal fibres in the different seasons.

*Rigidity modulus of the material of the fibres.* During the measurement of ribbon-width and convolutions, the fibres of Verum 262 and 1027 A. L. F. were classified, according to their appearance under the microscope into two classes (*a*) thin ribbon-like and (*b*) stout rod-like. Rigidity tests on fibres falling in the second class, which appeared cylindrical and had few convolutions, showed that they generally possessed high values of rigidity. From these observations the rigidity modulus of the material constituting the basal and the apical fibres was calculated according to the method suggested by Peirce [1923]. The coefficient of rigidity as given by Peirce can be calculated from: $\rho'' = ns^2$

($=$fibre rigidity$= \frac{8\pi^3 Il}{T^2}$ vide Appendix where $\rho$=couple per unit twist per unit length, $s$=area of cross section and $E$=a quantity depending on the shape of the cross section. For nearly cylindrical fibres falling in the second class $E=1$ and $s^2 = \frac{\pi^2 S^4}{16}$ where $\delta$ is the diameter of the fibre. We thus finally have $n = \frac{16\rho}{\pi^2 S^4}$.

This formula is applicable only to those fibres which have a nearly circular cross section, a rod-like appearance and comparatively few convolutions, and only such fibres were selected for the purpose of this calculation. The final results obtained for Verum 262 and 1027 A. L. F. are given below in Table V:

TABLE V

*Rigidity modulus of the material of the fibre, (base and apex)*

| Cotton | Region of the seed | $P = \frac{8\pi^3 Il}{T^2}$ x10⁻² dynes cm² | $\delta$ x10⁻²cm | $n = \frac{16\rho}{\pi^2\delta^4}$ 10″ dynes cm² |
|---|---|---|---|---|
| Verum 262 (Nagpur) | Base | 10·4 | 0·1452 | 0·3791 |
| | Apex | 10·6 | 0·1487 | 0·3515 |
| Surat 1027 A. L. F. | Base | 9·1 | 0·1832 | 0·1308 |
| | Apex | 10·8 | 0·1966 | 0·1171 |

It is seen that the rigidity modulus for the material is very nearly equal for the basal and the apical fibres of the same cotton although it varies considerably from one cotton to another. The finer variety, 1027 A. L. F., has a lower value than the coarser variety, Verum 262, its value being nearly one-third of that for the former. Peirce [1923] found that the average value of the rigidity modulus for two cottons (Sea Island and an Indian cotton) was $0{\cdot}23 \times 10''$ dynes/cm². This is nearly double of that found for Surat 1027 A. L. F. in the present tests but less than that obtained for Verum 262. These results show that the nature of the material deposited in fibres growing on different regions of a seed is the same though it may differ somewhat from cotton to cotton. Thus, if a high fibre-weight is observed for the apical fibres, it is due to the presence of a larger quantity of the material itself rather than to the deposition of a material of a higher density.

(*b*) *Fibres from all regions of the seed.*

The tests on fibres taken from all regions of the seed were confined only to Nandyal 14. The mean values of rigidity obtained for the base, apex, right flank, left flank of the seed and the combed hairs together with the absolute and percentage differences (calculated on the basis of the lower values) are given in Table VI.

TABLE VI

*Fibre rigidity, 10⁻² dynes cm² mean value differences : fibres from all regions of the seed, Nandyal 14.*

| Region | Mean | Difference between | Mean value differences | Percentage | Significant or non-significant |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| Base (B) | 3·11 | R—L | —0·01 | 0·3 | Not significant |
| Apex (A) | 4·42 | B—Flanks | —0·20 | 6·4 | Do. |
| Right Flank (R) | 3·31 | B—C | 1·20 | 62·8 | Significant |
| Left Flank (L) | 3·32 | A—Flanks | 1·11 | 33·5 | Do. |
| Combed hairs (C) | 1·91 | A—C | 2·51 | 131·4 | Do. |

Several interesting points emerge from a study of Table VI. It is seen in the first place that fibre-rigidity varies considerably over the surface of the seed, the highest value for the apex being nearly two and a half times as much as for the combed hairs. The variation, however, is not regular, the values for the right and the left flank being very nearly equal. Consequently, the value for either of the flanks may be taken for comparison with the other regions of the seed. From column 2 we next notice that the apical fibres are the most rigid, those from the flanks take the second place while those from the base are a close third. The combed hairs possess the lowest rigidity.

The frequency distributions and the statistical constants are given in Tables VII and VIII respectively.

TABLE VII

*Frequency distribution of fibre rigidity (dynes cm² 10⁻²) : fibres from all regions of the seed, Nandyal 14*

| Group | Base | Apex | Right flank | Left flank | Combed hairs |
|---|---|---|---|---|---|
| 0 | 18 | 6 | 8 | 5 | 38 |
| 1 | 28 | 11 | 22 | 13 | 47 |
| 2 | 25 | 19 | 34 | 38 | 20 |
| 3 | 21 | 29 | 37 | 36 | 23 |
| 4 | 19 | 26 | 16 | 23 | 10 |
| 5 | 10 | 20 | 11 | 21 | 4 |
| 6 | 16 | 12 | 12 | 8 | 3 |
| 7 | 5 | 12 | 4 | 2 | 3 |
| 8 | 2 | 7 | 5 | 3 | 2 |
| 9 | 1 | 4 | 3 | 1 | |
| 10 | 1 | 5 | 1 | | |
| 11 etc. | 2 | 3 | | | |
| TOTAL | 148 | 154 | 153 | 150 | 150 |
| *Mean* | 3·11 | 4·42 | 3·31 | 3·32 | 1·91 |

## TABLE VIII

*Frequency constants for the frequency distributions of fibre rigidity: ($10^{-2}$ dynes cm$^2$) fibres from al regions of the seed, Nandyal 14 Units.*

| Quantity | Base | Apex | Right flank | Left flank | Combed hair |
|---|---|---|---|---|---|
| Mean M | 3·11 | 4·42 | 3·31 | 3·32 | 1·91 |
| Q1 | 1·19 | 2·64 | 1·79 | 2·06 | 0·42 |
| Q3 | 4·55 | 5·93 | 4·41 | 4·44 | 2·88 |
| $e_1$ | 1·92 | 1·79 | 1·52 | 1·25 | 1·49 |
| $e_2$ | 1·44 | 1·50 | 1·10 | 1·12 | 0·97 |
| Q | 1·68 | 1·64 | 1·31 | 1·19 | 1·23 |
| E (S. O.) | 1·64 | 1·72 | 1·43 | 1·15 | 1·18 |
| .. | 2·44 | 2·55 | 2·12 | 1·71 | 1·75 |
| Cv | 78·3 | 57·6 | 64·1 | 51·7 | 91·9 |
| CA | 0·154 | 0·064 | 0·134 | 0·039 | 0·273 |
| Skewness | 0·513 | 0·528 | 0·595 | 0·418 | 0·976 |

Same notation as used in Table II.

## TABLE IX

*Mean fibre rigidity, Nandyal 14.*

| Region | Percentage of fibres in each region | | Mean rigidity $10^{-2}$ dynes cm$^2$ |
|---|---|---|---|
| | By weight | By number | |
| Base | 30·0 | 30·0 | 3·11 |
| Apex | 16·0 | 17·3 | 4·42 |
| Right flank | 23·0 | 20·7 | 3·31 |
| Left flank | 24·0 | 22·7 | 3·32 |
| Combed hairs | 7·0 | 9·3 | 1·91 |

| | |
|---|---|
| Straight mean | 3·21 |
| Weighted mean (by weight) | 3·33 |
| Weighted mean (by number) | 3·32 |
| Technological Reports (bulk mean) | 3·03 |

The distributions for the right flank, the left flank and the combed hairs resemble closely those for the base and the apex in as much as they all deviate from normality, as shown by the trend of values given in Table VII and the relevant constants in Table VIII. Consequently, we are again unable to apply the standard error test for judging the significance of differences and will, as before, resort to the quartile test. It is not necessary to give the details of the application of this test. It may only be stated that on applying this test it is found that the differences between the flanks, and between the base and the flanks are not significant, while those between other regions of the seed are significant.

The percentage distribution by weight of fibres on different regions of the seed and the unit fibre weight pertaining to each region are given in another publication [Koshal and Ahmad, 1932]. From a knowledge of these two quantities we can readily calculate the percentage distribution *by numbers* of fibres on different regions of the seed. We can then proceed a step further and calculate the weighted mean, both according to distribution by weight and distribution by number, of the values from the apex, base, etc. These means together with the 'straight' mean and the value for the bulk sample taken from the *Technological Reports on Standard Indian Cottons* [Ahmad, 1931]

are given in Table IX. It will be seen that the two weighted means are very nearly equal to the 'straight' mean showing that the effect of regional differences in rigidity is balanced to a large extent by the relative proportions of fibres on the surface of the seed. Again, the weighted means are only slightly higher than the mean for the bulk sample in spite of the large difference between the rigidities of the apical and the combed hairs. This is no doubt due to the relatively small number of the latter as compared with the remaining fibres on the seed, as also to the balancing effect of the high rigidity of the apical fibres with the low rigidity of the combed fibres.

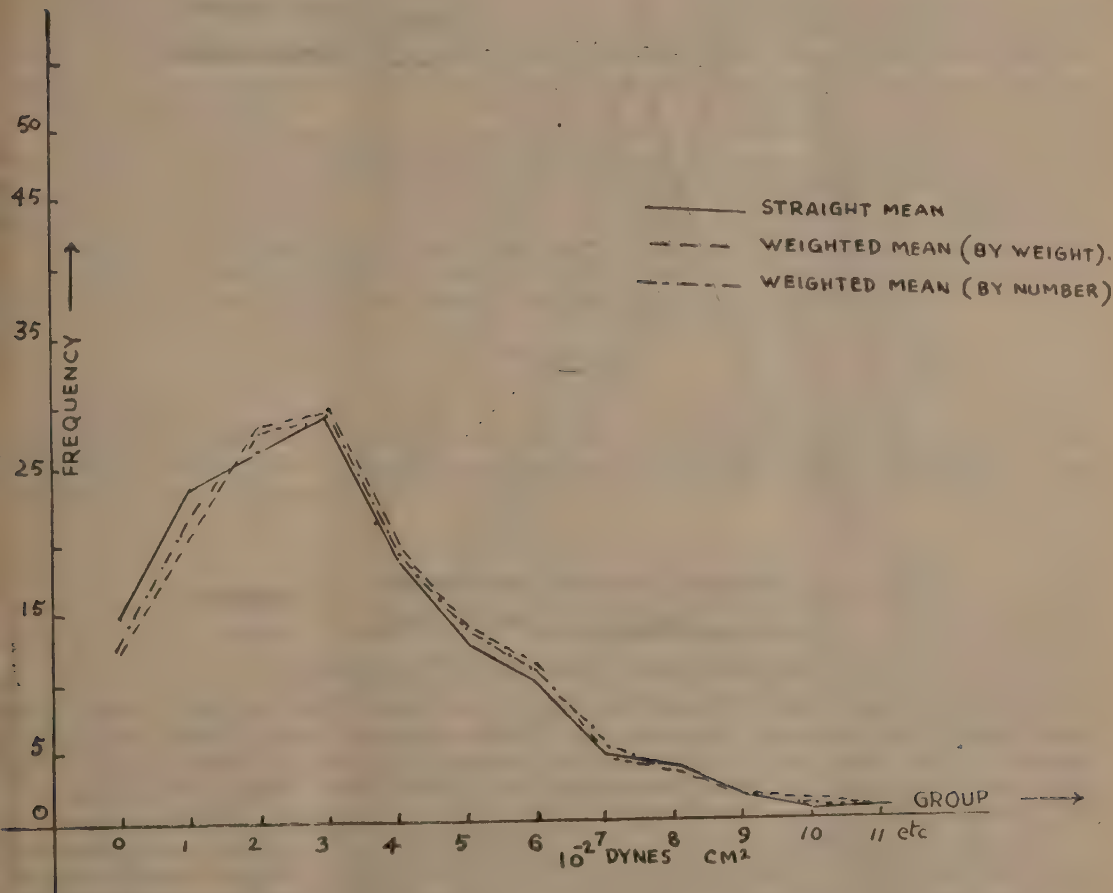


FIG. 2A. Frequency distribution of rigidity values for fibres of Nandyal 14.

The curves showing the frequency distributions of rigidity values for fibres from all regions of the seed of Nandyal 14 are given in Figs. 2A and 2B.

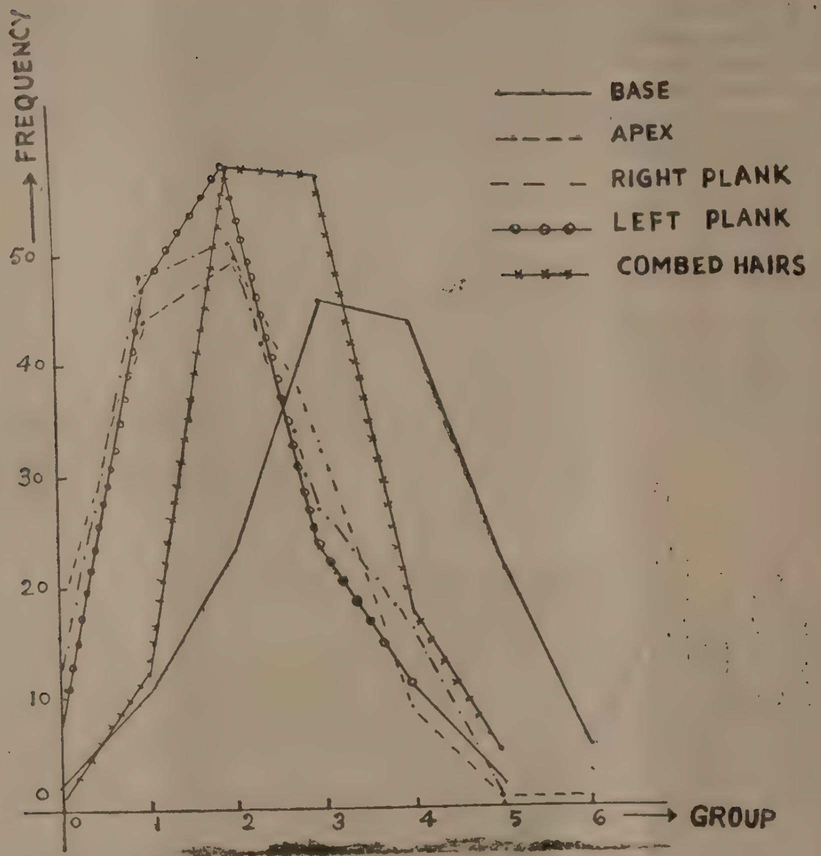


FIG. 2B. Frequency distribution of rigidity values for fibres of Nandyal 14.

It will be seen that these are of two distinct types, those for the basal and the combed hairs show definite J-shape tendency, while those for the other regions are model curves, which have deviated from the normal and are skew. The latter resemble the curves for fibre strength. The coefficient of asymmetry for these distributions given in Table VIII confirms this statement. This statistic is relatively small for the flanks and the apex as compared with that for the base.

In order to study the effect of the two types of distribution on the bulk sample, curves combining the values for all the five portions (both on the basis of the arithmetic and the weighted means) were drawn and superposed on the individual curves. The three curves utilising the mean values follow a similar course and lie fairly close to the curve for the basal fibres, which has a mild tendency towards J shape. It is interesting to note that these curves are very similar in type to that indicated by Khosal and Turner [1930] for Nandyal 14, when a small number of fibres was tested. In fact, their classification of the eight cottons under test according to the shape of the frequency distribution polygon for fibre rigidity is similar to the classification given previously in this paper. This deviation from a definite J-shape, as obtained by Khosal and Turner for 1027 A. L. F., to a mere mild tendency towards J-shape, is very probably due to the preponderating influence of the skew distributions for the fibres from the flanks and the apex. The study of the results for Nandyal 14 shows that the rigidity curve obtained for a bulk sample is not a simple curve, but a combination of J and skew distributions superposed upon one another and arising from a mixture of the fibres from all

parts of the seed. The influence of the basal and the combed hairs is felt strongly in the curve for the bulk sample, which accordingly acquires a mild J-shape tendency. Such a variety in types of curves for the different constituents of the population, as in most cases the composite population itself showing a type of its own, herein studied is peculiar to fibre rigidity. From this point of view it may be useful to study other cottons which show strong differences in the types of curves for the bulk sample and its various constituents.

(c) *Probable effect of a J-distribution on Spinning.*

A J-distribution indicates the presence of a large percentage of fibres of low rigidity. Such fibres on account of their pliability and suppleness can be twisted with ease without straining the fibre. But these like the combed fibres are generally weak and immature lacking structural solidarity and promote nep formation. Fibres should therefore possess sufficient rigidity to prevent clustering but not to resist twisting.

Turner and Venkataraman [1933] have found a correlation of 0·58 between fibre strength and fibre rigidity. While fibre strength would contribute directly towards yarn strength, the same fibres being too rigid resist a spin thus affecting its spinning capacity. The low correlation between fibre strength and yarn strength as well as the negative correlation −0·33 [Turner and Venkataraman, 1933] between fibre strength and spinning value may be partly due to the opposing influences of the two positively related properties, fibre rigidity and fibre strength, on the spinning quality. Cottons with moderate values of rigidity and strength may prove better than those with extreme values.

## Ribbon width

(a) *Base and apex.*

The frequency distribution of ribbon width for the basal and the apical fibres for the eight cottons tested are given in Table X. It will be noticed that the individual values are distributed over a fairly wide range in all cases.

Table X

*Ribbon width—frequency distribution*

| — | Nandyal 14 | | P. A. 4F | | C. A. 9 1928-29 | | C. A. 9 1929-30 | | Gadag I 1928-29 | | Gadag I 1927-28 | | Verum 262 (Nagpur) | | Surat 1027 A. L. F. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group $10^{-4}$ cms. | Base | Apex | Base | Apex | Base | Apex | Base | Apex | Base | Apex | Base | Apex | Base | Apex | Base | Apex |
| 9 | 1 | | | | | | | | 1 | | | | | | | |
| 10 | 1 | | | | | | 1 | | 2 | | 3 | | | | | |
| 11 | 3 | | | | 3 | 1 | 6 | | 11 | 3 | 14 | 2 | 3 | 3 | | |
| 12 | 4 | | | | 2 | 10 | 12 | 7 | 25 | 4 | 27 | 3 | 2 | 5 | 1 | |
| 13 | 11 | 2 | 1 | | 10 | 16 | 20 | 23 | 35 | 21 | 34 | 23 | 15 | 14 | 5 | |
| 14 | 19 | 6 | 2 | 1 | 19 | 23 | 33 | 27 | 37 | 31 | 32 | 28 | 22 | 17 | 7 | 1 |
| 15 | 27 | 9 | 5 | 0 | 39 | 40 | 29 | 36 | 16 | 24 | 26 | 34 | 23 | 38 | 14 | 6 |
| 16 | 21 | 19 | 8 | 4 | 35 | 27 | 24 | 29 | 15 | 36 | 9 | 32 | 20 | 28 | 21 | 13 |
| 17 | 22 | 20 | 8 | 8 | 23 | 18 | 14 | 23 | 7 | 20 | 7 | 11 | 21 | 19 | 22 | 13 |
| 18 | 14 | 28 | 12 | 10 | 9 | 11 | 4 | 7 | 3 | 15 | 2 | 9 | 28 | 17 | 27 | 23 |
| 19 | 15 | 29 | 26 | 23 | 4 | 4 | 3 | 2 | 2 | 1 | 1 | 4 | 9 | 7 | 16 | 27 |
| 20 | 9 | 22 | 27 | 30 | 2 | | 2 | 1 | 0 | 4 | | 3 | 4 | 2 | 21 | 20 |
| 21 | 6 | 8 | 20 | 25 | 1 | | 0 | | 1 | 1 | | 1 | 3 | 3 | 4 | 18 |
| 22 | 0 | 6 | 17 | 20 | 1 | | 2 | | | | | | 2 | 2 | 10 | 12 |
| 23 | 2 | 3 | 17 | 20 | 0 | | | | | | | | 1 | | 6 | 7 |

TABLE X—*contd.*

*Ribbon width—frequency distribution*—contd.

| —— | Nandyal 14 | | P. A. 4F. | | C. A. 9 1928-29 | | C. A. 9 1929-30 | | Gadag I 1928-29 | | Gadag I 1927-28 | | Verum 262 (Nagpur) | | S. 1027 A. L. F. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group $10^{-4}$ cms. | Base | Apex | Base | Apex | Base | Apex | Base | Apex | Base | Apex | Base | Apex | Base | Apex | Base | Apex |
| 24 | | 1 | 6 | 6 | 2 | | | | | | | | | | 0 | 5 |
| 25 | | 2 | 5 | 2 | | | | | | | | | | | 0 | 4 |
| 26 | | | 2 | 1 | | | | | | | | | | | 1 | 1 |
| 27 | | | | | | | | | | | | | | | | 1 |
| 28 | | | | | | | | | | | | | | | | 1 |
| *Total* | 155 | 155 | 156 | 150 | 150 | 150 | 150 | 155 | 155 | 160 | 155 | 150 | 153 | 155 | 155 | 152 |

TABLE XI

*Ribbon width $10^{-4}$ cm.—Mean values and frequency constants—base and apex*

| Cotton | | Mean M | $\frac{A-B}{B} \times 100$ | .. | Cv = $\frac{..}{M} \times 100$ | $Q_1$ | $Q_3$ | $e_1$ | $e_2$ | $\frac{Q_3-Q_1}{2}$ = Q | E (S. O.) | $\frac{e_1-e_2}{M}$ = CA | Skewness |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nandyal 14 | B | 16·26 | 12·5 | 2·569 | 15·8 | 14·54 | 18·07 | 1·72 | 1·82 | 1·77 | 1·734 | —0·006 | 0·180 |
| | A | 18·29 | | 2·283 | 12·5 | 16·69 | 19·70 | 1·60 | 1·41 | 1·50 | 1·540 | 0·010 | —0·038 |
| P. A. 4F. | B | 20·15 | 2·0 | 2·597 | 12·9 | 18·67 | 22·02 | 1·49 | 1·87 | 1·68 | 1·75 | —0·019 | 0·011 |
| | A | 20·56 | | 2·103 | 10·2 | 19·18 | 22·12 | 1·38 | 1·57 | 1·47 | 1·419 | —0·009 | 0·057 |
| C. A. 9 (1928-29) | B | 15·77 | —3·5 | 2·027 | 12·8 | 14·60 | 16·75 | 1·13 | 0·98 | 1·05 | 1·368 | 0·010 | 0·241 |
| | A | 15·20 | | 1·735 | 11·4 | 14·01 | 16·38 | 1·20 | 1·18 | 1·19 | 1·170 | 0·001 | 0·052 |
| C. A. 9 (1929-30) | B | 14·80 | 2·4 | 2·072 | 14·0 | 13·68 | 16·03 | 1·12 | 1·23 | 1·18 | 1·308 | —0·075 | 0·207 |
| | A | 15·15 | | 1·649 | 10·8 | 13·87 | 16·35 | 1·27 | 1·20 | 1·24 | 1·113 | —0·045 | 0·049 |
| Gadag I (1928-29) | B | 13·82 | 11·4 | 1·916 | 13·8 | 12·54 | 14·88 | 1·28 | 1·05 | 1·17 | 1·292 | 0·017 | 0·281 |
| | A | 15·39 | | 1·910 | 12·4 | 13·94 | 16·60 | 1·45 | 1·21 | 1·33 | 1·288 | 0·015 | —0·059 |
| Gadag I (1927-28) | B | 13·64 | 11·7 | 1·744 | 12·8 | 12·36 | 14·79 | 1·28 | 1·15 | 1·22 | 1·177 | 0·104 | 0·175 |
| | A | 15·23 | | 1·837 | 12·1 | 13·89 | 16·25 | 1·34 | 1·02 | 1·18 | 1·239 | 0·029 | 0·198 |
| Verum 262 (Nagpur) | B | 16·17 | —2·4 | 2·321 | 14·4 | 14·38 | 17·86 | 1·79 | 1·69 | 1·74 | 1·566 | 0·007 | 0·064 |
| | A | 15·79 | | 2·133 | 13·5 | 14·53 | 17·14 | 1·26 | 1·35 | 1·30 | 1·439 | —0·006 | 0·315 |
| 1027 A. L. F. | B | 17·94 | 9·0 | 2·556 | 14·2 | 16·11 | 19·70 | 1·83 | 1·76 | 1·80 | 1·724 | 0·004 | 0·132 |
| | A | 19·55 | | 2·628 | 13·4 | 17·78 | 21·16 | 1·78 | 1·61 | 1·70 | 1·773 | 0·009 | 0·296 |

B = Base. A = Apex
Same notation as used in Table II.

The mean values and the statistical constants calculated for these distributions are given in Table XI. Considering the mean values given in Column 2 of Table XI, it is found that with the exception of C. A. 9 (1928-29) and Verum 262, the mean ribbon width of the apical fibres is higher than that of the basal fibres.

Though these differences ranging from 2·0 to 12·5 per cent (in terms of the basal fibres) are not large, the cottons can be classified into two groups (1) Nandyal 14, Gadag I and 1027 A. L. F. for which the difference is nearly equal and relatively large ranging from 9·0 to 12·5 per cent and (2) P. A. 4F, C. A. 9 and Verum 262, for which again the difference is nearly equal but small ranging from 2·0 to 3·5 per cent only. It may be noted that the two exceptions mentioned above, viz. C. A. 9 (1928-29) and Verum 262, for which the basal fibres have a larger ribbon width, come in the second group.

As these differences are not only small in magnitude but vary in direction from cotton to cotton it would be necessary to examine statistically if they are beyond errors of random sampling. The necessity for such criterion becomes evident when it is seen that while the coefficient of variation ranging from 10·2 to 15·5 per cent is small and does not differ appreciably either from cotton to cotton or from region to region, it is greater than the percentage difference between the two regions. In the case of the cottons of the second group the regional difference is less than even twice the standard deviation.

The exact statistical test to be employed depends on the frequency distribution of ribbon width in the samples. An inspection of the frequency polygons drawn in Fig. 3, shows that the distributions are more or less normal, this can also be seen from the statistical constants given in Table XI which show that the values of $e_1$, $e_2$, Q and E (S. O.) are fairly close together for each distribution. Moreover the coefficient of asymmetry and skewness are fairly small ranging from 0·001 to 0·104 and from 0·011 to 0·315 respectively. It is therefore proposed to apply Fisher's $t$ test to judge the significance of differences in mean value between the two regions for a cotton.

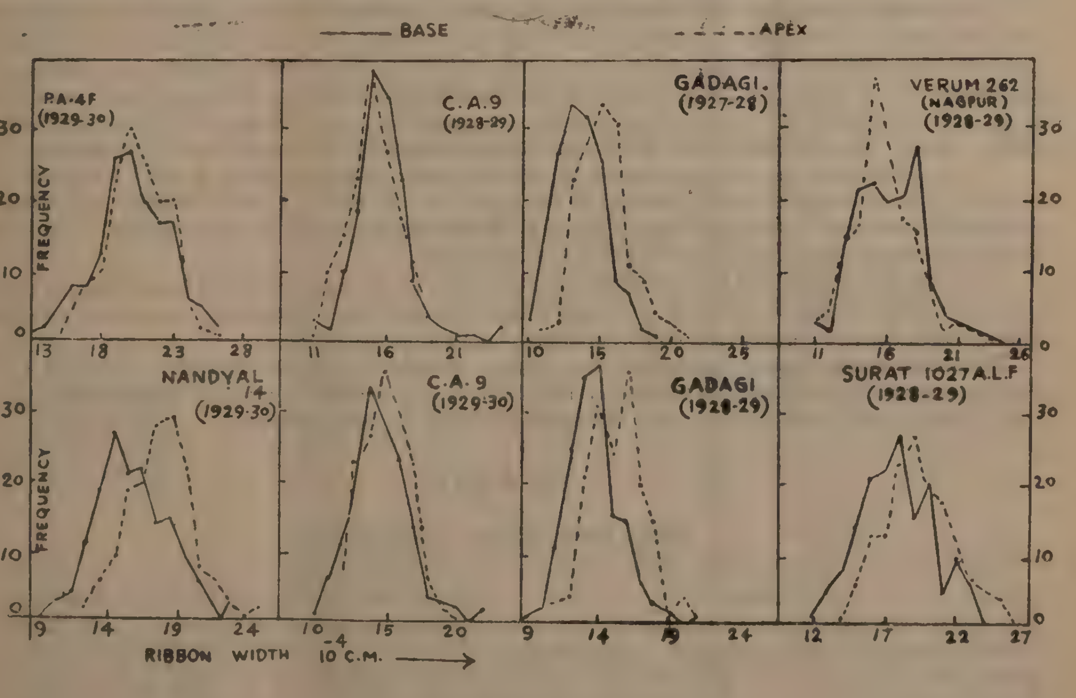


Fig. 3. Frequency Polygons.

The necessary data are calculated and given in Table XII.

TABLE XII

*Ribbon width $10^{-4}$ cm. : Significance of differences—base and apex*

| No. | Cotton | Base B | Apex A | A-B | n* | t | P | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1 | Nandyal 14 | 16·26 | 18·29 | 2·03 | 308 | 8·31 | <0·01 | Significant |
| 2 | P. A. 4F. | 20·15 | 20·56 | 0·41 | 304 | 1·49 | 0·1 to 0·2 | Not significant |
| 3 | C. A. 9 (1928-29) | 15·77 | 15·20 | —0·57 | 298 | 2·58 | <0·01 | Significant |
| 4 | C. A. 9 (1929-30) | 14·80 | 15·15 | 0·35 | 303 | 1·51 | 0·1 to 0·2 | Not significant |
| 5 | Gadag I (1928-29) | 13·82 | 15·39 | 1·57 | 313 | 7·22 | <0·01 | Significant |
| 6 | Gadag I (1927-28) | 13·64 | 15·23 | 1·59 | 303 | 7·73 | <0·01 | Significant |
| 7 | Verum 262 | 16·17 | 15·79 | —0·38 | 306 | 1·50 | 0·1 to 0·2 | Not significant |
| 8 | 1027 A. L. F. | 17·94 | 19·55 | 1·61 | 305 | 5·42 | <0·01 | Significant |

The remarks in the last column agree with the earlier conclusion that the cottons can be classified into two groups (1) Nandyal 14, Gadag I and 1027 A. L. F., for which the differences are significant and the apical fibres are broader and (2) Verum 262, and P. A. 4F for which the regional difference is negligible. C. A. 9 however is an exception for the difference between the apical and basal fibres is not only significant but, unlike other cottons, the apical fibres in the season 1928-29 have also a smaller width. But the sample for the season 1929-30 reveals no significant regional difference.

These conclusions are also supported by the frequency polygons given in Fig. 3 wherein the curves for the two regions nearly overlap in the case of P. A. 4F, C. A. 9 and Verum 262, while in the case of Nandyal 14, Gadag I and 1027 A. L. F. the curves for basal fibres shifted to the right would give approximately the curve for the apical fibres.

It is therefore concluded that while the ribbon width of the apical and the basal fibres is nearly the same for the cottons P. A. 4F, C. A. 9 and Verum 262, the fibres of the apical region have a larger ribbon width for the cottons Nandyal 14, Gadag I and 1027 A. L. F.

The shape of the frequency polygons may now be considered. From the curves drawn in Fig. 3 and from the statistical constants given in Table XI, it is concluded that these distributions in the two regions do not deviate much from the normal for any of these cottons.

TABLE XIII

*Ribbon width $10^{-4}$ cm. base and apex*

| Cotton | Base | Apex | Technological Reports (bulk) |
|---|---|---|---|
| Nandyal 14 | 16·26 | 18·29 | 16·52 |
| P. A. 4F. | 20·15 | 20·56 | 17·53 |
| C. A. 9 (1928-29) | 15·77 | 15·20 | 15·24 |
| C. A. 9 (1929-30) | 14·80 | 15·15 | 16·26 |
| Gadag I (1928-29) | 13·82 | 15·39 | 15·00 |
| Gadag I (1927-28) | 13·64 | 15·23 | 15·75 |
| Verum 262 (Nagpur) | 16·17 | 15·79 | 15·75 |
| 1027 A. L. F. | 17·94 | 19·55 | 18·05 |

In Table XIII the mean ribbon width of the basal and apical fibres as well as the mean for the bulk sample taken from the *Technological Reports* [Ahmad, 1931] are given for comparison. It is noticed therefrom that unlike the similarity between samples from the bulk and the different regions observed in regard to the frequency distribution, the mean for the bulk does not disclose any uniform relationship with either the basal or the apical fibres as was found in the case of fibre rigidity, probably due to the influence of the fibres from the flanks and the combed fibres which may have a different mean value as in the case of Nandyal 14 discussed later.

*Seasonal variations.* As in the case of rigidity only two cottons Gadag I and C. A. 9 were tested for two different seasons. From the Tables XI and XII it is seen that for C. A. 9 tested for 1928-29 and 1929-30 the difference in ribbon width between the two regions is small being -- 3·5 per cent and 2·4 per cent only in the respective seasons, but positive though not significant in the latter and negative but significant in the former season. For Gadag I tested for 1928-29 and 1927-28, however the ribbon width of the apical fibres is greater than that of the basal fibres by 11·4 per cent and 11·7 per cent respectively in the two seasons and both are significant.

This indicates that while the effect of season of growth on the relative difference in ribbon width between the basal and apical fibres is generally in appreciable, some cottons may give a differential response to season of growth.

(*b*) ***Fibres from all regions of the seed***

The tests again are confined to only one cotton, viz. Nandyal 14. The mean ribbon width of fibres from all the five regions as well as the difference between one region and another, calculated as a percentage of the lower value in each case, are given in Table XIV.

TABLE XIV

*Ribbon width $10^{-4}$ cm.: Significance of regional differences (fibres from all regions of the seed surface) —Nandyal 14*

| No. | Region | Mean | Difference between | Difference | Percentage difference | n | t | p | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | Base (B) | 16·26 | B-A | —2·03 | —12·5 | 308 | 8·31 | <0·01 | Significant |
| 2 | Apex (A) | 18·29 | B-R | —1·18 | —7·3 | 308 | 4·05 | <0·01 | Significant |
| 3 | Right flank (R) | 17·44 | B-L | —1·37 | —8·4 | 303 | 5·13 | <0·01 | Significant |
| 4 | Left flank (L) | 17·63 | B-C | —2·86 | —17·6 | 304 | 9·78 | <0·01 | Significant |
| 5 | Combed fibres (C) | 19·12 | A-R | 0·85 | 4·9 | 308 | 3·12 | <0·01 | Significant |
| 6 | Arithmetic mean | 17·75 | A-L | 0·66 | 3·7 | 303 | 2·66 | <0·01 | Significant |
| 7 | Weighted mean | 17·41 | A-C | —0·83 | —4·5 | 304 | 3·02 | <0·01 | Significant |
| 8 | Technological Reports: Bulk mean | 16·52 | R-L | —0·19 | —1·1 | 303 | 0·74 | 0·4 to 0·5 | Not significant |
| | | | R-C | —1·68 | —9·6 | 304 | 5·86 | <0·01 | Significant |
| | | | L-C | —1·49 | —8·5 | 299 | 5·63 | <0·01 | Significant |

It is seen therefrom that the combed hairs have the maximum ribbon width, the apical, the right and the left flanks, and the basal fibres following in order. The maximum difference in ribbon width which is between the basal and the combed fibres is 17·6 per cent and the minimum of 1·1 per cent is between the two flanks. Most of these differences are small and as such tests of significance are necessary.

The frequency distributions and the statistical constants are given in Tables XV and XVI respectively.

### TABLE XV

*Frequency distribution of ribbon width $10^{-4}$ cm., Nandyal 14*

| Group | Base | Apex | Right flank | Left flank | Combed fibres |
|---|---|---|---|---|---|
| 9 . . . . . | 1 | | | | |
| 10 . . . . . | 1 | | | | |
| 11 . . . . . | 3 | | | | |
| 12 . . . . . | 4 | | 1 | 1 | 1 |
| 13 . . . . . | 11 | 2 | 6 | 1 | 0 |
| 14 . . . . . | 19 | 6 | 8 | 7 | 3 |
| 15 . . . . . | 27 | 9 | 12 | 14 | 6 |
| 16 . . . . . | 21 | 19 | 29 | 19 | 15 |
| 17 . . . . . | 22 | 20 | 27 | 28 | 18 |
| 18 . . . . . | 14 | 28 | 22 | 38 | 19 |
| 19 . . . . . | 15 | 29 | 15 | 17 | 24 |
| 20 . . . . . | 9 | 22 | 14 | 18 | 20 |
| 21 . . . . . | 6 | 8 | 11 | 2 | 24 |
| 22 . . . . . | 0 | 6 | 2 | 3 | 6 |
| 23 . . . . . | 2 | 3 | 3 | 0 | 9 |
| 24 . . . . . | | 1 | 1 | 1 | 2 |
| 25 . . . . . | | 2 | 1 | 1 | 3 |
| 26 . . . . . | | | | | 1 |
| 27 . . . . . | | | | | |
| 28 . . . . . | | | | | |
| *Total No. of fibres* . . | 155 | 155 | 155 | 150 | 151 |
| MEAN . | 16·26 | 18·29 | 17·44 | 17·63 | 19·12 |

### TABLE XVI

*Frequency constants for the frequency distributions of ribbon width $10^{-4}$ cm.: fibres from all regions of the seed surface Nandyal 14*

| Constants | Base | Apex | Right flank | Left flank | Combed hairs |
|---|---|---|---|---|---|
| Mean M . . . . . . | 16·26 | 18·29 | 17·44 | 17·63 | 19·12 |
| f. . . . . . . | 2·569 | 2·283 | 2·510 | 2·027 | 2·529 |
| C. V. . . . . . . | 15·8 | 12·5 | 14·4 | 11·5 | 13·2 |
| $Q_1$ . . . . . . | 14·54 | 16·69 | 15·85 | 16·31 | 17·26 |
| $Q_3$ . . . . . . | 18·07 | 19·70 | 19·10 | 18·81 | 20·85 |
| $e_1$ . . . . . . | 1·72 | 1·60 | 1·59 | 1·32 | 1·86 |
| $e_2$ . . . . . . | 1·82 | 1·41 | 1·66 | 1·18 | 1·73 |
| Q . . . . . . | 1·77 | 1·50 | 1·62 | 1·25 | 1·80 |
| E (S. O.) . . . . . | 1·734 | 1·540 | 1·693 | 1·368 | 1·706 |
| $C_A$ . . . . . . | —0·006 | 0·010 | —0·004 | 0·007 | 0·007 |
| Skewness . . . . . | 0·189 | —0·038 | 0·328 | —0·076 | 0·078 |

(Same Notation as used in Table II).

It will be observed therefrom that as before, the *t* test can be applied to judge the significance of these regional differences in ribbon width. The relevant data are calculated and given in Table XIV from which it is concluded that except between the right and left flanks the difference between every other region is significant. The fibres on the two flanks have practically the same ribbon width.

The combed fibres have the maximum width probably caused by a premature detachment from the seed coat and consequent deficiency in cell wall development whereby it is flattened when the fibres collapse on boll ripening.

The apical fibres come next in order. As will be shown later the apical fibres, though narrower than the combed fibres, have in all probability a greater wall thickness than the latter, which are perhaps immature. Ribbon width would thus be an inadequate measure of fineness of a cotton as one with a larger width may be finer though weaker, being thin walled, than another with less width but greater wall thickness.

The fibres from the flanks, very similar between themselves, have a smaller width than the apical but larger than the basal fibres which, however, have the minimum width.

The mean value for the bulk sample as given in the *Technological Reports* [Ahmad, 1931] as well as the straight and weighted means calculated from the average values for the different regions are given in Table XIV. It is seen that the arithmatic mean and the weighted mean are nearly the same and slightly higher than the mean for the bulk which, however, corresponds to the mean ribbon width of the basal fibres.

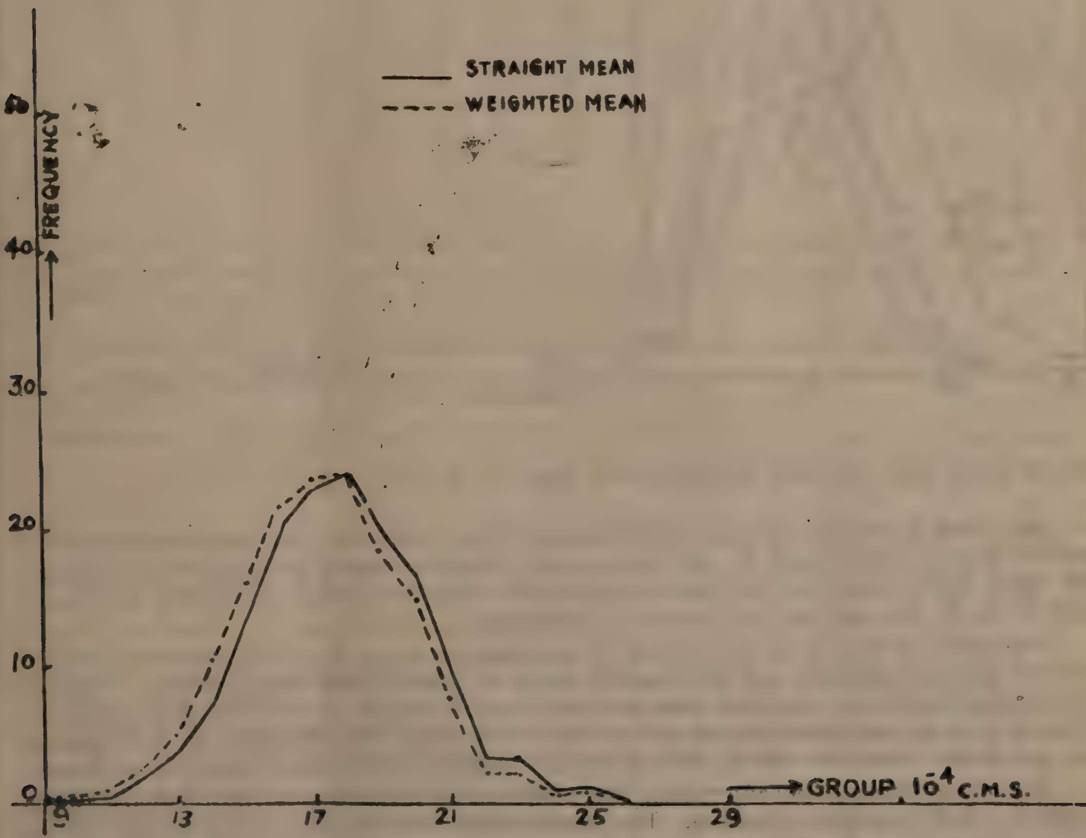


FIG. 4A. Ribbon width: Frequency distribution curves; fibres from all regions of the seed, Nandyal 14

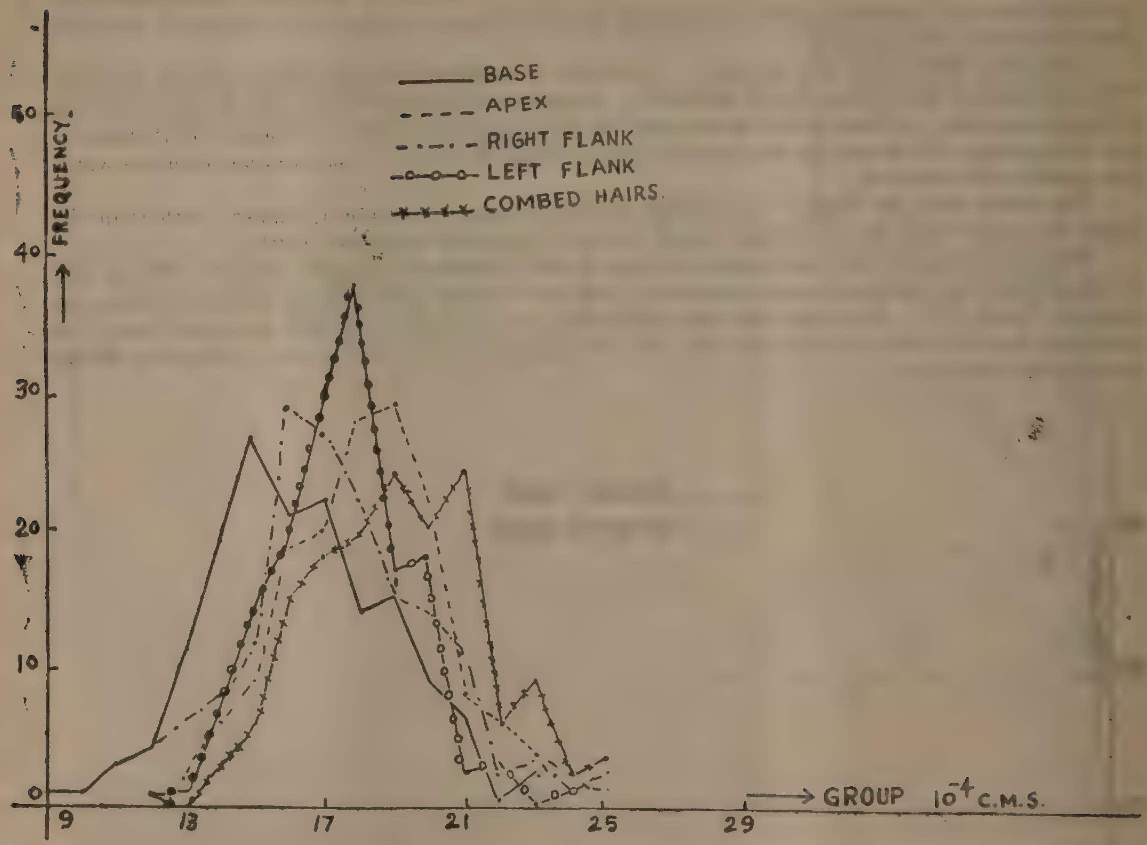


**Fig. 4B. Ribbon width**: Frequency distribution curves; fibres from all regions of the seed, Nandyal 14

The curves showing the frequency distribution of ribbon width for fibres from all regions of the seed are drawn in Figs. 4A and B. All the curves are similar and more or less normal in shape. The curve for the basal fibres lies more towards the left while that for the combed fibres to the right while curves for the apex and the flanks lie in between.

Superposed on these is the curve drawn by combining the values for all the five regions, on the basis of both the arithmatic and the weighted means, to give the bulk sample pattern. The two curves creep beside each other and both are nearly normal shaped. A study of these curves for Nandyal 14 shows that unlike the case of fibre rigidity not only is the distribution for each region of the seed surface normal but also for the bulk sample composed of fibres from these different regions.

Koshal and Turner [1930] after testing 3000 fibres have concluded that the distribution of ribbon width in a bulk population is normal. The present results show that this is true not only for the whole population but also for its constituent elements, i.e. even when fibres from individual regions of the seed are tested. Such a distribution therefore must be an inherent quality of fibre development on any part of the seed and is not just a result of the mixture of fibres from various regions of a seed or from various seeds. This result contrasts with the results for fibre rigidity in which case the distributions in the different regions were dissimilar

*Convolutions*

(a) *Base and apex*

The frequency distribution of the number of convolutions per mm. for the basal and the apical fibres are given in Table XVII for the eight cottons tested.

TABLE XVII

*Frequency distribution of convolutions per mm. : Base and apex*

| Group | Nandyal 14 | | P. A. 4F. | | C. A. 9 (1928-29) | | C. A. 9 (1929-30) | | Gadag I (1928-29) | | Gadag I (1927-28) | | Verum 262 (Nagpur) | | 1027 A. L. F. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B | A | B | A | B | A | B | A | B | A | B | A | B | A | B | A |
| 0 | 2 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 0 | 1 |
| 1 | 11 | 44 | 12 | 0 | 1 | 2 | 2 | 6 | 0 | 0 | 0 | 4 | 2 | 24 | 3 | 18 |
| 2 | 24 | 49 | 17 | 4 | 9 | 11 | 10 | 29 | 6 | 6 | 6 | 16 | 17 | 38 | 29 | 72 |
| 3 | 46 | 33 | 37 | 33 | 21 | 27 | 14 | 39 | 15 | 27 | 14 | 32 | 28 | 31 | 71 | 49 |
| 4 | 44 | 9 | 37 | 38 | 25 | 41 | 28 | 35 | 23 | 48 | 15 | 38 | 59 | 37 | 40 | 11 |
| 5 | 22 | 1 | 34 | 50 | 25 | 38 | 30 | 29 | 36 | 42 | 39 | 38 | 28 | 14 | 10 | 1 |
| 6 | 6 | 1 | 13 | 16 | 26 | 25 | 28 | 11 | 42 | 24 | 38 | 14 | 9 | 7 | 2 | 0 |
| 7 | | | 5 | 8 | 19 | 4 | 23 | 4 | 23 | 11 | 29 | 5 | 6 | 0 | | |
| 8 | | | 1 | 1 | 20 | 2 | 10 | 2 | 6 | 2 | 9 | 3 | 2 | 0 | | |
| 9 | | | | | 4 | 0 | 4 | 0 | 4 | 0 | 4 | 0 | | | | |
| 10 | | | | | | | 1 | 0 | | | 1 | 0 | | | | |
| *Total* . | 155 | 155 | 156 | 150 | 150 | 150 | 150 | 155 | 155 | 160 | 155 | 150 | 153 | 155 | 155 | 152 |

B=Base ; A=Apex

The statistical constants for these distributions are calculated and given in Table XVIII.

TABLE XVIII

*Frequency constants for the frequency distribution of the number of convolutions per mm. : Base and apex*

| 1 | 2 | | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cotton | | Mean M | $\frac{A-B}{B} \times 100$ | $\sigma$ | $\frac{\sigma}{M} \times 100 = Cv$ | $Q_1$ | $Q_3$ | $e_1$ | $e_2$ | $\frac{Q_3-Q_1}{2} = Q$ | E (S. O.) | $\frac{e_1-e_2}{M} = CA$ | Skewness |
| Nandyal 14 . | B | 3·40 | —43·3 | 1·276 | 37·5 | 2·55 | 4·21 | 0·85 | 0·80 | 0·83 | 0·86 | 0·012 | —0·692 |
| | A | 1·93 | | 1·123 | 58·1 | 1·02 | 2·71 | 0·91 | 0·78 | 0·84 | 0·76 | 0·069 | 0·173 |
| P. A. 4F . | B | 3·87 | 16·6 | 1·513 | 30·1 | 2·82 | 4·96 | 1·05 | 1·09 | 1·07 | 1·02 | —0·011 | —0·008 |
| | A | 4·51 | | 1·196 | 26·5 | 3·56 | 5·30 | 0·95 | 0·79 | 0·87 | 0·81 | 0·035 | —0·100 |
| C. A. 9 (1928-29) . | B | 5·33 | —17·5 | 1·904 | 35·7 | 3·81 | 6·84 | 1·52 | 1·51 | 1·51 | 1·28 | 0·002 | 0·031 |
| | A | 4·40 | | 1·361 | 30·9 | 3·46 | 5·38 | 0·95 | 0·98 | 0·96 | 0·92 | —0·007 | 0·220 |
| C. A. 9 (1929-30) . | B | 5·26 | —28·3 | 1·829 | 34·8 | 3·96 | 6·57 | 1·30 | 1·32 | 1·31 | 1·23 | —0·004 | 0·011 |
| | A | 3·77 | | 1·430 | 39·3 | 2·65 | 4·80 | 1·12 | 1·03 | 1·08 | 1·00 | 0·023 | 0·235 |

## TABLE XVIII

*Frequency const nts for the frequency distribution of the number of convolut on per mm. : Base and apex*

| 1 | 2 | | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cotton | Mean M | | $\frac{A-B}{B}\times 100$ | $\sigma$ | $\frac{\sigma}{M}\times 100 = Cv$ | $Q_1$ | $Q_3$ | $Q_1$ | $Q_2$ | $\frac{Q_1-Q_3}{2}=Q$ | E (S. O.) | $\frac{c_1-c_2}{M}=0$ | Skewness. |
| Gadag I (1928-29) . | B | 5·38 | —14·1 | 1·554 | 28·9 | 4·32 | 6·41 | 1·06 | 1·03 | 1·05 | 1·05 | 0·004 | —0·003 |
| | A | 4·62 | | 1·296 | 28·0 | 3·70 | 5·48 | 0·93 | 0·85 | 0·89 | 0·87 | 0·016 | 0·222 |
| Gadag I (1927-28) . | B | 5·59 | —25·6 | 1·621 | 29·0 | 4·65 | 6·70 | 0·94 | 1·11 | 1·03 | 1·09 | —0·031 | —0·105 |
| | A | 4·16 | | 1·459 | 35·0 | 3·05 | 5·14 | 1·12 | 0·98 | 1·05 | 0·98 | 0·033 | 0·017 |
| Verum 262 (Nagpur) . | B | 4·03 | —26·1 | 1·387 | 34·4 | 3·17 | 4·79 | 0·86 | 0·76 | 0·81 | 0·91 | 0·024 | 0·023 |
| | A | 2·98 | | 1·443 | 48·4 | 1·83 | 4·07 | 1·14 | 1·09 | 1·12 | 0·97 | 0·017 | 0·117 |
| 1027 A. L. F. . . | B | 3·25 | —25·9 | 0·963 | 29·6 | 2·65 | 3·88 | 0·60 | 0·63 | 0·62 | 0·65 | —0·008 | 0·185 |
| | A | 2·41 | | 0·829 | 39·8 | 1·81 | 3·02 | 0·59 | 0·61 | 0·60 | 0·56 | —0·008 | 0·235 |

B = Base ; A = Apex

The notation is the same as used in Table II

From column 3 of Table XVIII, in which the percentage mean differences in convolutions per mm. between the two regions calculated in terms of the basal fibres are given, it is observed that except in the case of P. A. 4F. the basal fibres have a greater number of convolutions per mm. than the apical, the difference ranging from 14·1 per cent for Gadag I(1928-29) to 43·3 percent for Nandyal 14. For P. A. 4F., however, the apical fibres have 16·6 per cent more number of convolutions per mm. The difference in seven cases ranges between 14·1 per cent and 28·3 per cent and it is 43·3 per cent only for the one remaining cotton, Nandyal 14. Since the coefficient of variation is fairly high ranging from 28·0 per cent to 58·1 per cent and greater than the percentage differences in mean values, the significance of the differences must, as before, be ascertained by statistical tests.

Since an inspection of the frequency polygons drawn in Fig. 5 and the statistical constants given in Table XVIII show that the distributions are approximately normal, Fisher's method of variance ($Z$ test) will be applied.

The relevant data are calculated and the results given in Table XIX.

## TABLE XIX

*Convolutions per mm. : Significance of differences : Base and apex (Method of variance)*

| Cotton | Base (B) | Apex (A) | A-B | $n_1$ | $n_2$ | Z | Z for P = ·01 for $n_1=1$ & $n_2=\infty$ | Remarks |
|---|---|---|---|---|---|---|---|---|
| Nandyal 14 . . . . | 3·40 | 1·93 | —1·47 | 1 | 308 | 2·37 | 0·95 | Significant |
| P. A. 4F. . . . . | 3·87 | 4·51 | 0·64 | 1 | 304 | 1·41 | 0·95 | ,, |
| C. A. 9 (1928-29) . . . | 5·33 | 4·40 | —0·93 | 1 | 298 | 1·58 | 0·95 | ,, |
| C. A. 9 (1929-30) . . . | 5·26 | 3·77 | —1·49 | 1 | 303 | 2·03 | 0·95 | ,, |
| Gadag I (1928-29) . . | 5·38 | 4·62 | —0·76 | 1 | 313 | 1·54 | 0·95 | ,, |
| Gadag I (1927-28) . . | 5·59 | 4·16 | —1·43 | 1 | 303 | 2·05 | 0·95 | ,, |
| Verum 262 . . . . | 4·03 | 2·98 | —1·05 | 1 | 306 | 1·82 | 0·95 | ,, |
| 1027 A. L. F. . . . . | 3·25 | 2·41 | —0·84 | 1 | 305 | 2·10 | 0·95 | ,, |

It is seen therefrom that the differences are significant in all the cases even including that of P. A. 4F., which has given results contrary to others.

It is therefore concluded that with the exception of P. A. 4F. the convolutions in the apical fibres are more widely spaced than in the basal fibres. For P. A. 4F. however, the convolutions are more crowded in the apical fibres. For C. A. 9 (1929-30), Gadag I (1927-28), Verum 262 and 1027 A. L. F. the relative difference between the two regions is practically same, ranging between 25·6 per cent and 28·3 per cent only.

While the results of the number of convolutions per mm. were considered so far, those of the total number of convolutions *per fibre* may now be taken up.

In Table XX the number of convolutions per fibre for the basal and the apical regions are given along with the percentage differences between the regions in the case of each cotton.

TABLE XX

*Convolutions per fibre : Mean values and percentage differences—base and apex*

| Cotton | Base B | Apex A | $\frac{A-B}{B} \times 100$ |
|---|---|---|---|
| Nandyal 14 | 71 | 36 | —49·2 |
| P. A. 4F. | 76 | 82 | 7·8 |
| C. A. 9 (1928-29) | 110 | 78 | —29·1 |
| C. A. 9 (1929-30) | 108 | 68 | —37·0 |
| Gadag I (1928-29) | 98 | 79 | —19·4 |
| Gadag I (1927-28) | 107 | 74 | —30·8 |
| Verum 262 (Nagpur) | 81 | 52 | —35·8 |
| 1027 A. L. F. | 68 | 49 | —27·9 |

It is seen therefrom that with the exception again of P. A. 4F the number of convolutions is always greater for fibres from the base than the apex, the difference ranging between 19·4 per cent and 37·0 per cent only in all cases except Nandyal 14 for which it is 49·2 per cent. In the case of P. A. 4F, however, the apical fibres have 7·8 per cent greater number of convolutions. It appears, therefore, that in a good number of the cases considered the basal fibres have about 25 to 30 per cent greater number of convolutions than the apical fibres, though for Nandyal 14 the difference is nearly 50 per cent ; for P. A. 4F, however, the apical fibres are more convoluted. These results are generally in accordance with the conclusions of Winters and Chaney [1924] that 'Increased density of hair population on the cotton seed coat is definitely associated with increased number of convolutions per inch', as the number of convolutions both per unit length, and per fibre, are generally greater for the basal fibres which are more densely distributed on the seed. But their further conclusions 'That increased length was found to be associated with decrease in the number of convolutions per inch', is not substantiated by these results as the apical fibres with a smaller mean length are less convoluted both per fibre and per unit length. The influence of these regional differences on the mean of a bulk sample can be seen from Table XXI, in which the means for both the apical and the basal fibres as well as the mean for the bulk taken from the *Technological Reports* [Ahmad, 1931], are given.

TABLE XXI

*Convolutions per cm.: Comparative Values: Base, apex and Technological Reports*

| Cotton | Base | Apex | Technological Reports (bulk) |
|---|---|---|---|
| Nandyal 14 | 34 | 19 | 27 |
| P. A. 4F. | 39 | 45 | 42 |
| C. A. 9 (1928-29) | 53 | 44 | 50 |
| C. A. 9 (1929-30) | 53 | 38 | 43 |
| Gadag I (1928-29) | 54 | 46 | 48 |
| Gadag I (1927-28) | 56 | 42 | 45 |
| Verum 262 (Nagpur) | 40 | 30 | 28 |
| 1027 A. L. F. | 32 | 24 | 25 |

It is seen therefrom that except for Verum 262, in other cases, the mean for the bulk lies between that for the base and the apex though nearer the latter for five cottons including Verum 262. This is due, judging from the results for Nandyal 14 discussed later, to the fact that for 75 per cent of the fibres on a seed comprising those from the apex, the flanks and the combed fibres, the mean value is nearly equal to that for the apical fibres but less than that for the basal fibres.

Considering together the regional differences both as regards convolutions and ribbon width discussed earlier, some interesting results are obtained. Denham [1923] states 'That Miss. G.G. Clegg of this Laboratory has shown that the ratio of ribbon width to wall thickness is directly correlated with the number of convolutions per unit length'. The present tests have revealed that generally the apical fibres have a greater width and smaller number of convolutions, which therefore indicate that the wall thickness of the apical fibres is greater. The relatively higher fibre weight and greater fibre strength found for the apical fibres by Koshal and Ahmad [1932] also point to the same conclusion. Further the same result is arrived at by calculating the value of $\bar{L}\times\sqrt{\rho}$ ($\bar{L}$=mean length and $\rho$=hair rigidity) which according to Peirce [1924] is 'a good measure of the degree of thickening'. The relevant data for all the eight cottons are calculated and given in Table XXII.

TABLE XXII

*Product of hair rigidity and mean length: Base and apex*

| Cotton | Mean length $\bar{L}$ (cm)* | | Mean hair rigidity $10^{-2}$ Dynes cm$^2$ | | $\bar{L}\sqrt{\rho}$=S | | $\delta$= $S_B$-$S_A$ |
|---|---|---|---|---|---|---|---|
| | Base | Apex | Base | Apex | Base ($S_B$) | Apex ($S_A$) | |
| Nandyal 14 | 2·46 | 1·93 | 3·11 | 4·42 | 4·34 | 4·06 | 0·28 |
| P. A. 4F. | 2·03 | 1·70 | 1·97 | 5·06 | 2·85 | 3·82 | —0·97 |
| C. A. 9 (1928-29) | 2·34 | 1·98 | 3·26 | 4·55 | 4·23 | 4·22 | 0·01 |
| C. A. 9 (1929-30) | 2·28 | 1·90 | 2·82 | 3·89 | 3·83 | 3·75 | 0·08 |
| Gadag I (1928-29) | 2·03 | 1·80 | 2·00 | 4·77 | 2·87 | 3·93 | —1·06 |
| Gadag I (1927-28) | 2·06 | 1·83 | 1·99 | 5·64 | 2·91 | 4·35 | —1·44 |
| Verum 262 (Nagpur) | 2·08 | 1·83 | 4·17 | 8·77 | 4·25 | 5·42 | —1·17 |
| 1027 A. L. F. | 2·34 | 2·11 | 3·00 | 6·66 | 4·05 | 5·44 | —1·39 |

* $\bar{L}$ is taken from the investigations by Koshal and Ahmad [1932] Table VI and converted into metric units; $\rho$ is taken from Table II col. 4 of this paper.

It is seen therefrom that for five cottons the value of the product is much higher for fibres from the apex than the base. For C. A. 9 of both the seasons, the difference is negligible. Only in the case of Nandyal 14, the basal fibres show a higher value.

It can therefore be concluded that the apical fibres generally have a greater degree of thickening of the cell wall than the basal fibres.

*Seasonal variations.* As in other cases the results of only two cottons C. A. 9 and Gadag I are available for two different seasons. From Tables XVIII and XIX it is found that season of growth has no appreciable effect on the number of convolutions *per mm.* in a given region of the seed for either cotton, except for the apical fibres of C. A. 9 for which the sample for 1928-29 has a greater number than for 1929-30. While the basal fibres in any one season have a greater number of convolutions *per mm.*, the relative percentage difference between the regions slightly varies with season, being lower for the 1928-29 sample and higher for the sample of the other season for both cottons.

It may, however, be noted from Table XX that except for the basal fibres of C. A. 9 the mean number of convolutions *per fibre* as well as their relative difference between the regions varies with season of growth.

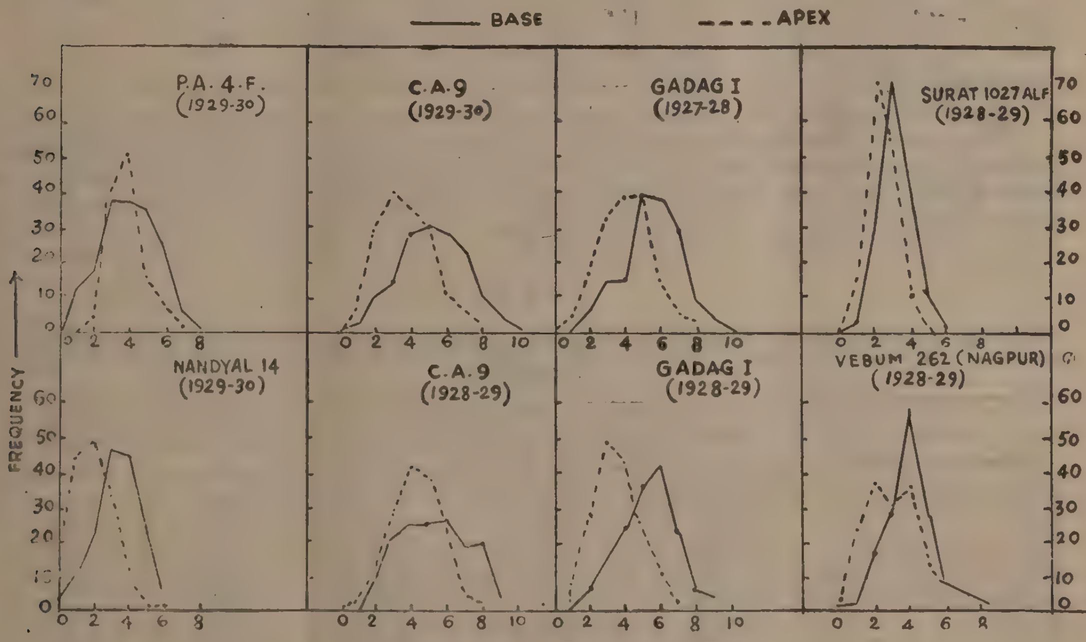


FIG. 5. Frequency Polygons: Convolutions per mm.

The frequency polygons for the distributions given in Table XVII are drawn in Fig. 5. It is seen that the form of the curve is nearly the same for all cottons for the two regions and is nearly normal. In many cases like Nandyal 14, Gadag I and 1027 A. L. F. a lateral shift of the curves for apical fibres in the positive direction along the X-axis will nearly fit the curves for the basal fibres, showing that the form of distribution is typical irrespective of the variety of cotton or the region of origin. The statistical constants given in Table XVIII, viz. $e_1$, $e_2$, Q. E (S. O.), $C_A$ and skewness also support this observation. Koshal and Turner [1930] have shown that in a bulk sample the convolutions are so distributed as to depart very little from normal. The present investigation shows that this is true not only for the sample as a whole but also for fibres on different regions of the seed surface which ultimately compose the bulk.

(*b*) ***Fibres from all regions of the seed.***

D

### Table XXIII

*Frequency distribution of the number of convolutions per mm.—base, apex, right flank, left flank and combed fibres, Nandyal 14*

| Group | Base | Apex | Right flank | Left flank | Combed hairs |
|---|---|---|---|---|---|
| 0 | 2 | 18 | 12 | 8 | 1 |
| 1 | 11 | 44 | 48 | 47 | 12 |
| 2 | 24 | 49 | 51 | 58 | 58 |
| 3 | 46 | 33 | 27 | 24 | 57 |
| 4 | 44 | 9 | 16 | 11 | 18 |
| 5 | 22 | 1 | 1 | 2 | 5 |
| 6 | 6 | 1 | | | |
| *Total* . . . . | 155 | 155 | 155 | 150 | 151 |
| *Mean* . . . . | 3·40 | 1·93 | 2·00 | 1·99 | 2·68 |

As before, the fibres from different regions are tested for only one cotton, viz. Nandyal 14.

The frequency distribution of the number of convolutions per mm. for fibres from the different regions of the seed surface, base, apex, right and left flanks, and the combed fibres are given in Table XXIII. The mean values and the statistical constants for these distributions are given in Table XXIV.

### Table XXIV

*Frequency constants for the frequency distribution of convolutions per mm.: Fibres from all regions: Nandyal 14*

| — | Base | Apex | Right flank | Left flank | Combed hairs |
|---|---|---|---|---|---|
| Mean M . . . . | 3·40 | 1·93 | 2·00 | 1·99 | 2·68 |
| $Q_1$ . . . . | 2·55 | 1·02 | 1·11 | 1·18 | 1·98 |
| $Q_3$ . . . . | 4·21 | 2·71 | 2·74 | 2·54 | 3·29 |
| $e_1$ . . . . | 0·85 | 0·91 | 0·89 | 0·81 | 0·70 |
| $e_2$ . . . . | 0·80 | 0·78 | 0·74 | 0·55 | 0·61 |
| Q . . . . | 0·83 | 0·84 | 0·82 | 0·68 | 0·66 |
| $\sigma$ . . . . | 1·276 | 1·121 | 1·101 | 1·030 | 0·933 |
| E (S. O.) . . . . | 0·860 | 0·757 | 0·742 | 0·695 | 0·629 |
| Cv . . . . | 37·5 | 58·1 | 55·0 | 51·9 | 34·8 |
| CA . . . . | —0·012 | 0·069 | 0·075 | 0·128 | 0·023 |
| Skewness . . . . | —0·069 | 0·173 | 0·294 | 0·269 | 0·150 |
| Convolutions per fibre . | 71 | 36 | 44 | 45 | 51 |

Same Notation as in Table II

Considering the mean values it is seen that the number of convolutions per mm. differs from region to region, the basal fibres having the maximum number of 3·40 per mm., and the apical fibres the minimum of 1·93 per mm. The fibres from both the flanks have almost the same number of convolutions per mm., viz. 2·00 and 1·99, differing little from the apical fibres. The combed hairs have an intermediate value of 2·68 per mm. The fibres may thus be divided into three groups—basal, combed and rest— in descending order of average number of convolutions per mm.

As before, the mean values, percentage differences between any two regions calculated on the basis of the lower value, and the significance of these differences obtained by applying the method of variance (Z test), are given in Table XXV.

TABLE XXV

*Convolutions per mm.: Significance of Differences: All regions of the seed: Nandyal 14—method of variance*

| Region | Mean | Difference between | Difference | Percentage difference | $n_1$ | $n_2$ | Z | Z for P=·01 $n_1=1$ & $n_2=\infty$ | Significance |
|---|---|---|---|---|---|---|---|---|---|
| Base (B) | 3·40 | B-A | 1·47 | 76·2 | 1 | 308 | 2·37 | 0·95 | Significant |
| Apex (A) | 1·93 | B-R | 1·40 | 70·0 | 1 | 308 | 2·33 | 0·95 | Significant |
| Right flank (R) | 2·00 | B-L | 1·41 | 70·9 | 1 | 303 | 2·36 | 0·95 | Significant |
| Left flank (L) | 1·99 | B-C | 0·72 | 26·9 | 1 | 304 | 2·60 | 0·95 | Significant |
| Combed hairs (C) | 2·68 | A-R | —0·07 | 3·6 | 308 | 1 | 0·61 | 4·38* | Not significant |
| | | A-L | —0·06 | 3·1 | 303 | 1 | 0·81 | 4·38* | Not significant |
| | | A-C | —0·75 | 38·9 | 1 | 304 | 1·84 | 0·95 | Significant |
| | | R-L | —0·07 | 3·5 | 303 | 1 | 2·19 | 4·38* | Not significant |
| | | R-C | —0·68 | 34·0 | 1 | 304 | 1·99 | 0·95 | Significant |
| | | L-C | —0·69 | 34·7 | 1 | 299 | 1·81 | 0·95 | Significant |

* Z for $n_1=\infty$ and $n_2=1$, for P=0·01

It is found therefrom that except for fibres between the two flanks, and between the apex and the flanks the other regional differences are significant. It is therefore concluded that the basal fibres come first with a maximum number of convolutions per mm. the combed fibres next with a smaller number. while the fibres from the apex and the two flanks come last and have practically the same number of convolutions per mm.

*Convolutions per fibre: All regions of the seed.* In Table XXIV the mean number of convolutions per fibre have been given for each of the five regions. Here again it is seen that the basal fibres with 71 twists are most convoluted and the apical fibres the least with 36 twists. The combed fibres again occupy an intermediate position. As regards the fibres from the two flanks while they have practically the same value. it is however less than for the combed fibres but more than that for the apex. unlike the number of twists per unit length. This is to be expected as the fibres from the flanks have a greater mean length than the apical fibres, while the number of convolutions per mm. is the same for both the regions.

This variation in the total number of convolutions without a variation in their linear arrangement for nearly 50 per cent of the fibres. appears to support the view of Clegg and Harland [1924] that 'the form of the curve (of distribution of convolutions) is predetermined by environmental conditions prevailing during the period of growth in length of the hair'.

TABLE XXVI

*Number of Convolutions per mm. and per fibre: All regions of the seed: Nandyal 14*

| Region | Convolutions per mm. | Percentage of fibres in each region | | Convolutions per fibre |
|---|---|---|---|---|
| | | by weight | by number | |
| Base | 3·40 | 30 | 30·0 | 71·3 |
| Apex | 1·93 | 16 | 17·3 | 36·3 |
| Right flank | 2·00 | 23 | 20·7 | 44·3 |
| Left flank | 1·99 | 24 | 22·7 | 45·3 |
| Combed fibres | 2·68 | 7 | 9·3 | 50·9 |

In Table XXVI the average number of convolutions per mm. and per fibre are given for the different regions along with the percentage of fibres in the respective regions, both by weight and by number. From this the straight mean, and the weighted mean both by weight, and by number, are calculated and given below. For comparison the mean value for the bulk sample taken from the *Technological Reports* [Ahmad, 1931] is also given.

| — | Technological Reports Bulk mean | Straight Mean | Weighted mean by number | Weighted mean by weight |
|---|---|---|---|---|
| Convolutions per mm. | 2·70 | 2·40 | 2·45 | 2·47 |
| Convolutions per fibre | 62·5 | 49·6 | 51·9 | 51·9 |

It is seen from these figures that the mean value given in Technological Reports is higher than the other means in both cases. The differences among the three calculated means, are however inappreciable, except for the convolutions per fibre for which the straight mean is slightly smaller than the weighted mean.

The number of convolutions per mm. as given in *Technological Reports*, viz. 2·70 lies approximately midway between the means for the apical and the basal fibres, 1·93 and 3·40 respectively, and agrees with the mean for the combed fibres, 2·68. The average number of convolutions per fibre 62·5 given in *Technological Reports* is between the mean for the basal and the combed fibres and higher than for the other three regions.

*Frequency polygons for the distribution of convolutions : All regions of the seed.* The frequency polygons for the distribution of convolutions per mm. given in Table XXII are drawn in Fig. 6.

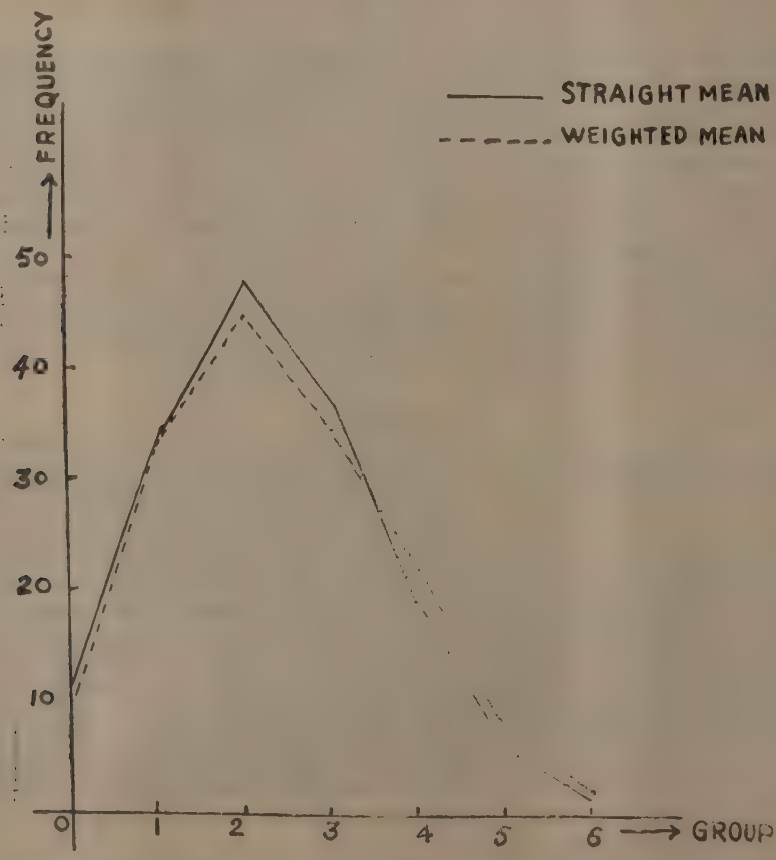


FIG. 6A. Frequency polygons : Convolutions per mm. : All regions of the seed, **Nandyal 14**

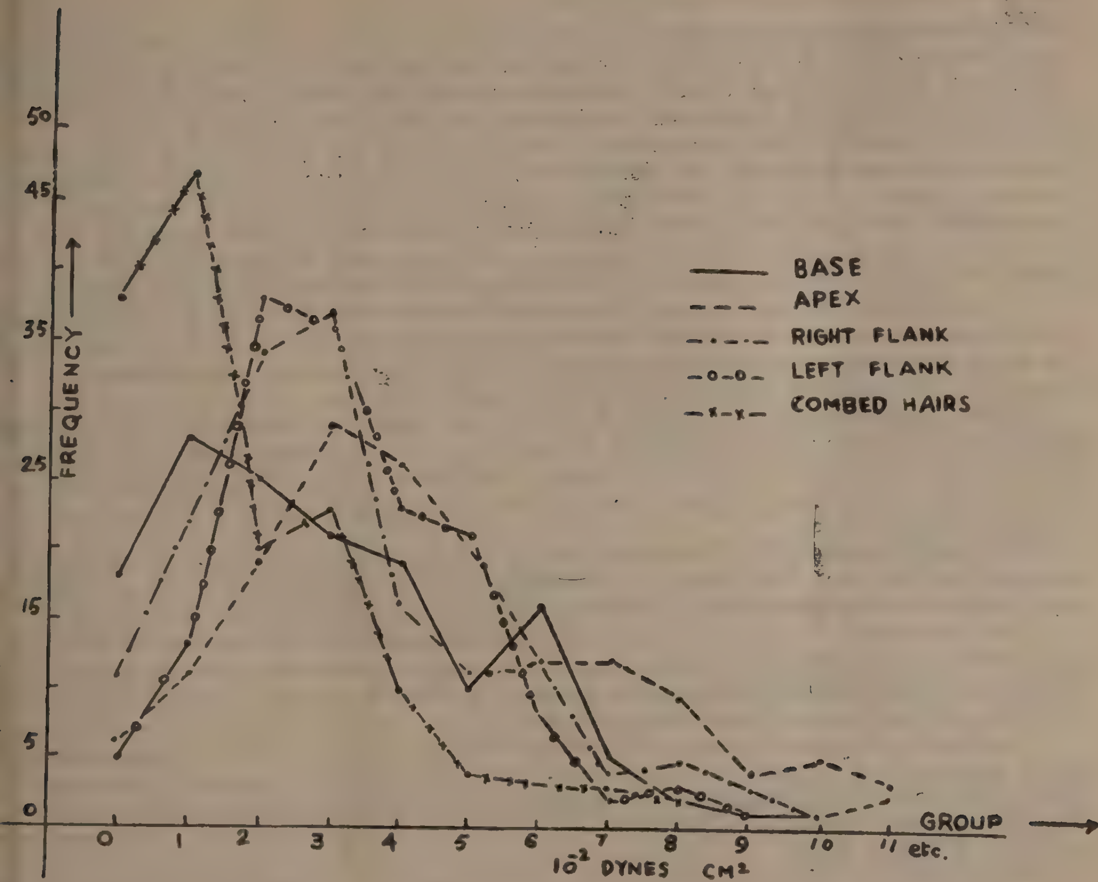


FIG. 6B. Frequency polygons: Convolutions per mm.: All regions of the seed, Nandyal 14

It is observed therefrom that all the polygons have nearly the same form and unlike those for rigidity are nearly normal. Except for the base and the apex, the curves for other regions nearly overlap. Koshal and Turner [1930] have shown that the general shape of the curve of convolutions is very nearly normal. From the present results it is found that the distribution in each individual region—fibres from which ultimately constitute the bulk sample—is similarly normal. Thus when a number of samples each with a normal distribution are mixed to yield the bulk the resulting distribution has also been normal.

This similarity in the form of distribution of convolutions among fibres from different regions even including the combed fibres which are probably undeveloped fibres indicates that the view of Clegg and Harland [1924] mentioned earlier that the form of distribution is predetermined by environment during the growth is true not only for the distribution in single fibres but also among a group of fibres, even though the convolutions are actually manifested after the fibre desiccates and collapses.

Superposed on these curves, are given those obtained by combining them on the basis of (1) straight mean, and (2) weighted mean (by weight), to thus represent the pattern of a bulk sample. These curves are almost identical and similar to the others being approximately normal.

*Probable causes of regional differences in fibre properties*

This investigation has shown that as much variation in the properties of the fibres on any one region of the seed can be expected as there are in a bulk sample and that there are considerable differences in the average fibre properties from region to region of the seed. While these tests do not claim to elucidate fully the causes of such variations a few general remarks may be offered.

(1) The nutritive system in the seed as envisaged by Balls [ 1915 ] is such that ' the vascular tissue enters the seed by its stalk, runs along the side and then breaks up at the wide butt of the seed into short distributing branches ', thus fostering a better growth at the base at the expense of the apical region. The space for deposit of nutrient matter in the matrix is larger at the base than at the funicle or its approaches. Even a shortage in the supply store will naturally affect the last portion to which the food is supplied, viz. the funicular end as has also been alluded to by Balls [1915].

(2) A likely result of the first cause is the belated commencement of growth of lint at the apex as compared with the base, as stated by Matthews [ 1924 ] and Bowman [ 1908 ]. In addition, if lint length development is arrested after about the 25th day of flowering, apical fibres would be shorter than the basal ones, assuming a uniform rate of lint extension.

(3) The arrangement of the ovules in the ovary is such that they are crowded at the point of attachment, while large space is allowed at the farther end of the maturing ovules in the enclosing space provided by the base of the pistil or stigma. The adherence of the funicle to the placenta and the hard stalk of the stigma affects the growth of fibres at this end by constant pressure against the cells of the palisade layer.

The primary consequence of the above causes is the shortening of lint length at the apex as compared with the base. The changes in other properties are a result of this and the continuation of the growth processes after cessation of lint length development on or about the 25th day.

The shorter lint at the apex admits the same nutrient matter (as the flow becomes more and more uniform) to be deposited in a shorter length in the apical fibres which thus have a greater wall thickness as inferred earlier. The comparative scarcity of fibres in this part lessens the competition for food supply and aids thickening of the cell wall.

This thicker wall naturally prevents the convolutions from showing up, due to enormous resistive forces, as stated by Balls [ 1915 ] and Bowman [ 1908 ]. The stout wall endows the fibre with a high rigidity, as shown by the examination of fibres with abnormally high rigidity by Peirce [ 1923 ]. The slight tendency for greater ribbon width among the apical fibres may be due to the thicker wall as stated by Balls [ 1928 ].

The second type of variation noted above, viz. differences in the properties of the fibres on any one region of the seed suggesting a common genetical basis are most probably due to the differential nutrition supplied to the elementary cells during their growth and decay on the outer epidermis of the seed and their consequent reaction to different environmental conditions. In so far as the history of the fibres on any one part of the seed surface is concerned, the internal and external conditions of growth would be nearly the same, only if there is simultaneity in the birth of lint cells. Balls [1915] and Barritt [ 1932 ] hold the view that the differentiation of epidermal cells into lint hairs is primarily a single day phenomenon, while Turner [ 1929 ], Gulati, [ 1930 ], and others are of the opinion that it is a phenomenon spread over a number of days. The general variation observed in these tests appears to favour the latter view. As a consequence of a time lag in the birth and growth of neighbouring fibres the reactions of the growing lint hairs to varying conditions of temperature, humidity, sunshine and nutrient supply would result in the endowment of different properties to the neighbouring fibres.

These results also suggest a partial answer to a question raised by Turner [ 1929 ] about the rate of nutrient available to different regions of the seed during the lengthening and thickening stages of the fibres. The stunting of lint length has been made up by a thick wall in the apical fibres which suggests that the flow of nutrient, perhaps deficient in the early stages in this region, has tended to become more uniform during the later stages. The ratio between the flow of nutrient in the lengthening and the thickening stages seems smaller for the apical than for the basal fibres.

## Summary and Conclusion

While the differences in the fibre properties from region to region on the surface of the cotton seed have been investigated as regards (1) length, (2) weight, and (3) strength, by Koshal and Ahmad, the present tests deal with three more properties (1) rigidity, (2) ribbon width and (3) convolutions.

The materials are the same standard Indian cottons as were used in the previous investigation, viz. Nandyal 14, P. A. 4F., C. A. 9 (1928-29), C. A. 9 (1929-30), Gadag I (1928-29), Gadag I (1927-28), Verum 262 (Nagpur), and 1027 A. L. F., the slivers having been conjointly prepared by us. For all the eight samples fibres from the base and the apex were tested.

In the case of Nandyal 14 only, fibres from the other regions, viz. right flank and left flank and the combed fibres were also tested.

The experimental methods used are the same as those in vogue at the Technological Laboratory of the Indian Central Cotton Committee, Bombay.

From the analysis of the results of this investigation the following conclusions have been drawn :

(1) The fibres on the apical region of the seed possess higher fibre rigidity than those on the basal region, the difference between the mean values for the two regions varying from cotton to cotton and ranging between 39·0 per cent for C. A. 9 (1929-30) and 183·4 per cent for Gadag I (1927-28).

The combed fibres have the lowest rigidity and the apical fibres the maximum, the difference between them being 131·4 per cent.

The frequency distribution of fibre rigidity is asymmetrical not only for the base and the apex but also for the other regions as well. But while it is skew for the apical fibres, a J-shape tendency is observed for the basal fibres as also for a bulk sample.

The rigidity modulus for the material of the fibre remains practically the same for the basal and the apical regions though differing from cotton to cotton.

(2) The fibres in the apical region have practically the same ribbon width as those in the basal region for P. A. 4F, C. A. 9 and Verum 262, while for Nandyal 14, Gadag I and 1027 A. L. F. the apical fibres are significantly broader, the difference ranging from 9·0 per cent to 12·5 per cent from cotton to cotton.

The combed fibres have the maximum ribbon width with the apical, the right and the left flanks, and the basal fibres following in the given order. The maximum difference, which is between the basal and the combed fibres, is 17·6 per cent and it is significant, while the minimum difference between the two flanks is 1·1 per cent and not significant, the differences between all the other regions, however, being significant.

The frequency distribution of ribbon width is practically normal not only for the bulk but for each region also, unlike that of fibre rigidity for which the distributions in the different regions are dissimilar.

(3) The difference in the number of convolutions per mm. between fibres from the apical and the basal regions varies from 14·1 per cent for Gadag I (1928-29) to 43·3 per cent for Nandyal 14, and is statistically significant in each case. With the exception of P. A. 4F., the convolutions in the apical fibres are more widely spaced than in the basal fibres. In P. A. 4F., however, the convolutions are more crowded in the apical fibres. Generally the basal fibres have 25-30 per cent greater number of convolutions per fibre.

Judging from the ratio of ribbon width to convolutions as shown by Clegg, and the values of the product, length $\times \sqrt{\text{hair rigidity}}$ as shown by Peirce, it is inferred that the apical fibres generally have a greater wall thickness.

The basal fibres have the highest number of convolutions both per fibre and per unit length. While the number of convolutions *per mm.*, or their linear density is lowest in the fibres from the flanks and the apex, the total number of convolutions *per fibre* is lowest in the apical fibres, those from the flanks and the combed fibres coming next in order.

The form of distribution of convolutions hardly differs either from cotton to cotton or from region to region on the seed surface, being normal for the bulk sample as well as for the fibres from the different regions of the seed.

These variations in the fibre properties, not only within a given region on the seed surface but also as between regions, are attributed to the time lag in the differentiation of neighbouring epidermal cells into lint hairs and the belated commencement of lint growth at the funicular end with a comparatively simultaneous cessation of lint length development, these again being the result of a relatively copious supply of nutrient matter at the base of the seed, particularly in the initial stages.

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## Appendix

### *Fibre rigidity*

The fibre rigidity is calculated from the usual formula for a torsion pendulum $n = \frac{8 \pi I l}{T^2 a^4}$ where $n$=coefficient of rigidity, I=moment of inertia of suspended rod, $l$=length of fibre, T=periodic time and $a$=radius of the fibre, assuming the fibre to be a cylinder. Hence $\pi a^2$=A=area of cross section, $n = \frac{8 \Pi^3 I l}{T^2 A^2}$. Assuming that even though fibres differ in shape of cross section, the sectional area is less likely to vary from fibre to fibre and so taking A nearly constant, $n = \frac{8 \Pi^3 I l}{T^2}$ is the coefficient calculated and taken to represent fibre rigidity.

But as already noticed by Auerbusch [1923] a cotton fibre is ribbon-like and not cylindrical; further it is not a uniform cylinder but a twisted ribbon and, therefore, the above formula would not strictly be applicable.

Even as a comparative measure of the resistance offered by fibres to a torsional force, it is defective in as much as the assumptions underlying the formula may not be equally valid in the case of all fibres. This may be illustrated by analysing the effect of convolutions on hair rigidity.

If the convolutions are all in one direction then the initial torque applied through the inertia rod would further twist the fibre if the convolutions are in the same direction as the twist, or untwist the fibre if in the opposite direction. The effect becomes more complicated if, as they usually are, the directions of the convolutions themselves are often reversed. The torsion couple would meet with resistance by these twists before the torque would reach the top support. And this resistance would increase or decrease with the number of convolutions, decreasing or increasing respectively the periodic time. Apart from degree of wall thickness convolutions alone would thus influence the hair rigidity.

This analysis finds justification in the observed effect of humidity on hair rigidity, which can at least partly be explained by the change in the number of convolutions. A rise in humidity decreases convolutions [Denham. 1923] increasing the periodic time (of the torsion pendulum) thus decreasing the fibre rigidity, as found by Peirce [1924].

The twisting couple may not thus be able to exert its influence along the entire free length of the suspended fibre whereby taking the length as $l$ would be inaccurate. If the convolutions are in different directions the inaccuracy increases.

A close examination of the fibre convolutions and of the rotation of the fibre at different points along its length from the free to the fixed end, when the fibre is under torsional stress might yield useful information.

The determination of fibre rigidity at different parts along the length of a fibre, instead of treating a whole fibre as a unit, would perhaps be more in consonance with the spinning processes which do not necessarily twist the entire length of a fibre at the same instant. Testing such short lengths would also minimise the effect of convolution on the hair rigidity formula.

Furthermore, even small variations in fibre diameter as it occurs in the fourth power in the formula would seriously affect hair rigidity.

Another point that was noticed during the present tests was the kinked appearance of some of the fibres suspended by the inertia rod ; obviously the weight of the rod was insufficient to stretch the fibre taut. And the formula would not be strictly applicable to such a system which may be linkened unto a degenerated open spiral.

The structure of the fibre as one made up of a number of concentric longitudinal tubes with intervening space, each tube having a fibrillar structure according to Balls [1928] makes the fibre non-homogeneous and the application of the formula would not be correct as any abnormality in the outer layers would seriously affect the torsion as it is in these layers that the strain is greatest as pointed out by Poynting and Thomson [1913]. The relative number of growth rings and their inter-ring distances might also affect rigidity.

Two modifications of the formula may now be considered : Since in a bulk sample the majority of the fibres would be more ribbon shaped than cylindrical, disregarding the effect of convolutions, we may use De St. Venant's [Poynting and Thomson,] formula for the torsional oscillations of a thin strip :

If $c$ is the couple required to produce a rate of twist $\varphi$, then $c = n\varphi\pi \dfrac{a^3 b^3}{a^2+b^2}$. If $b$ is small compared with $a$, $c=n\varphi\pi a b^3$ ($2a$ and $2b$ are the major and minor axes of the elliptical sections of the strip, $n$=coefficient of rigidity).

For the cotton fibres, $b$ may be regarded as relatively constant as compared with $a$ ; and $a$ may be taken as half the mean measured width. Hence, $c = \mathrm{I}\ddot{\theta} = n\varphi\pi a b^3$

If $\theta$ = total twist $= \pi a b^3 n\,\theta/l$.

And $b$ being constant, $\mathrm{T} \propto 2\pi\sqrt{\dfrac{\mathrm{I}\,l}{\pi n a}}$

When T is periodic time $\therefore\ \mathrm{T}^2 \propto \dfrac{4\pi \mathrm{I}\,l}{na}$

Putting $n = n_1$ $\qquad n_1 \propto \dfrac{4\pi \mathrm{I}\,l}{\mathrm{T}^2 a}$

$$\propto \frac{8\pi^3 \mathrm{I}\,l}{\mathrm{T}^2} \cdot \frac{\mathrm{I}}{a}$$

Thus the value of hair rigidity obtained in these tests, divided by half the width of the fibre, may be a better index of fibre rigidity.

TABLE I.

*Fibre rigidity values*

| Cotton | $\eta = \frac{8\pi^3 Il}{T^2}$ dynes cm² $10^{-2}$ | | | $\eta_1 = 2\,\eta/\alpha$ dynes cm $10^{-3}$ | | | $\eta_2 = \eta/\omega_1{}^2$ dynes cm-⁴ gm² $10^{10}$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | B | A | $\frac{A-B}{B} \times 100$ | B | A | $\frac{A-B}{B} \times 100$ | B | A | $\frac{A-B}{B} \times 100$ |
| Nandyal 14 | 3·11 | 4·42 | 42·2 | 3·83 | 4·83 | 26·1 | 0·81 | 0·83 | 2·4 |
| P. A. 4F. | 1·97 | 5·06 | 156·8 | 1·95 | 4·93 | 152·8 | 0·63 | 0·59 | —6·4 |
| C. A. 9 (1928-29) | 3·26 | 4·55 | 39·6 | 4·14 | 5·97 | 44·3 | 1·14 | 1·13 | —0·9 |
| C. A. 9 (1929-30) | 2·82 | 3·89 | 38·0 | 3·81 | 5·13 | 34·7 | 0·98 | 1·00 | 2·1 |
| Gadag I (1928-29) | 2·00 | 4·77 | 138·5 | 2·89 | 6·20 | 113·6 | 0·91 | 0·99 | 8·8 |
| Gadag I (1927-28) | 1·99 | 5·64 | 183·4 | 2·92 | 7·39 | 153·3 | 1·03 | 1·15 | 11·6 |
| Verum 262 | 4·17 | 8·77 | 110·3 | 5·16 | 11·12 | 115·2 | 0·98 | 1·38 | 40·7 |
| 1027 A. L. F. | 3·00 | 6·66 | 122·0 | 3·34 | 6·84 | 104·8 | 1·16 | 0·73 | —37·1 |

B = Base ; A = Apex.

The above Table gives the values of n and $n_1$ calculated according to the above formula. It is seen that the modified measure of fibre rigidity does not show any appreciable improvement over the usual one.

A second modification may be considered. Since $\frac{8\,\pi I l}{T^2\,\alpha^4} = \frac{8\,\pi^3 I l}{T^2\,(\pi\alpha^2)^2} = \frac{8\,\pi^3 I l}{T^2\,A^2}$ (the symbols having the usual significance) $A \times l$ gives the volume of the fibre and $A l\sigma$, where $\sigma =$ density of the material of the fibre, gives the weight of the fibre, assuming $\sigma$ to be constant from fibre to fibre or from cotton to cotton, we have

$$\eta^1{}_2 = \frac{8\,\pi^3 I l}{T^2\,A^2} = \eta/A^2$$

If $A\sigma =$ weight of a fibre $= \omega$

$$\eta^1{}_2 \text{ Then, } = \frac{\eta.\ l^2\,\rho^2.}{\omega^{12}}$$

In practice, the fibre weight and fibre rigidity are determined on different sets of fibres and the mean lengths of the fibres in each case are not generally identical. Hence if $W_1 =$ fibre weight per unit length then $\omega = \omega_1\, l$ Omitting the costant $\rho$, $\eta_2 = \frac{\eta}{\omega^{12}}$ may be taken to represent the comparative rigidity coefficient of the fibre for each cotton. In Table I of the Appendix, taking the values of $\eta$ from the present tests and $\omega_1$ from the results of Koshal and Ahmad [1932], the calculated values of $\eta_2$ and their regional differences are given. The range of these differences hardly exceeds 40 per cent. The cottons can be grouped into two classes (1) Verum 262 and 1027 A.L.F. for which the regional differences are large and (2) the rest for which the differences are small. It is to be noted that unlike $\eta$ or $\eta_1$, the basal fibres give a higher value of $\eta_2$ in a few cases. For different seasons for a given cotton the relative regional difference is not appreciably altered.

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# EFFECT OF COMPOSITION ON MOISTURE ABSORPTION PROPERTIES OF JAGGERY

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ONE of the important characters that enhance the market value of jaggery is its keeping quality : for the purpose of this paper, this has been considered as equivalent to the ability of the jaggery to resist absorption of moisture on exposure to humid air as the micro-organisms causing the actual deterioration can function only under favourable moisture conditions. In South India, particularly in places of heavy rainfall like Malabar and districts on the west coast, greater value is attached by the buyer to this character than even to its colour. The jaggery trader in evaluating his material is usually guided by its apparent hardness as this has generally a high correlation with keeping quality. But a surer method would be to measure its hygroscopic power on exposure to artificial atmospheres of definite relative humidities during a given period of time.

For the purpose of laboratory studies, atmospheres of any required relative humidity can be produced and maintained by keeping sulphuric acid of known density in closed desiccators [1921]. In all the experiments described in this paper, atmospheres of various relative humidities were obtained by this method only.

It is generally accepted that keeping quality of jaggery is intimately associated with its chemical composition : there however appears to be a difference of opinion as regards the nature of the particular constituent or constituents that control this important character. Rao and Ganapathy Iyer [1923] mainly from a comparison of the analytical results of a large number of jaggery samples with reference to their moisture-absorbing capacities, came to the conclusion that reducing sugars and chlorides exercised a dominating influence. Norris, Viswanath and Nair (1922) attributed the softening of cocoanut jaggeries to the excessive amounts of calcium chloride present therein. Varahalu [1935] has however concluded that organic non-sugars play a much more important role on the keeping quality of jaggery than any other of its ingredients. In view of the different conclusions arrived at by the previous workers and in view of the important nature of the problem, it was thought worthwhile to reopen investigations on this question in greater detail.

## Experimental procedure

Laboratory experiments were conducted on the following lines :

(1) Glucose, levulose, gums, separated from canejaggery, and chlorides and sulphates of sodium, potassium and calcium were added individually to different portions of pure white sugar solution and these were converted into solid products by concentrating them over direct flame in the laboratory under as uniform conditions as possible. These jaggeries were analyzed and their moisture-absorbing capacities compared at definite relative humidities by keeping them in desiccators containing sulphuric acid of appropriate density and noting the change in weight.

(2) The reducing sugar content of sugar solution and cane juice was altered by changing the reaction before concentration and the jaggeries obtained by concentrating them were analyzed and their keeping qualities examined.

(3) Sugarcane and cocoanut jaggeries were extracted with ethyl alcohol or treated with other organic reagents and the treated materials were analyzed and compared for their keeping qualities.

### *Determination of Moisture Absorption by Jaggery at a Particular Relative Humidity*

The sample of jaggery was well ground in a porcelain mortar and 5 gm. of the ground material were uniformly spread in a shallow, flat-bottomed weighing bottle 6 cm. in diameter and 3½ cm. deep.

Samples belonging to a particular experiment were placed in open weighing bottles of the same size and were all kept in a single desiccator containing dilute sulphuric acid of the requisite density at the laboratory temperature. The weighing bottles were closed with their corresponding lids just before weighing and the weights were noted daily for a period of about three weeks for each experiment. The position of the weighing bottles within the desiccator were changed from day to day so that each sample occupied various places in the desiccator before the conclusion of a particular experiment.

The original moisture in the samples taken for moisture-absorption studies was determined by weighing out separate portions of the above at the same time, and drying them to constant weight at the temperature of the steam oven after mixing them with well-cleaned sand. The dry matter was then calculated. To the amount of moisture thus found, was added the moisture absorbed at the conclusion of the experimental period and the total amount was expressed as a percentage of the dry matter in the sample.

Each experiment described in the paper envisaged the study of a particular question and therefore consisted of a control in addition to the different treatments. As all the samples relating to a particular experiment were placed within one and the same desiccator kept at the laboratory temperature, the small variations in temperature met with in the laboratory during the course of the day and from day to day may be presumed, without much error, to affect equally the moisture absorption rates of the samples of the different treatments relating to the particular experiment. The conclusions drawn will not therefore be vitiated by this circumstance of temperature fluctuations.

For the same reason, changes in the percentages of relative humidities at which moisture absorptions were determined for different experiments will not affect the nature of the conclusions drawn for any particular experiment.

### *Effect of dextrose and levulose on the keeping quality*

Increasing amounts of laboratory samples of dextrose and levulose were added to bazaar sugar solution and these were concentrated in the laboratory to consistency suitable for conversion into a solid product. The final products so obtained were analyzed and their moisture-absorbing capacities were compared at 75 per cent relative humidity.

TABLE I

*The effect of the addition of dextrose and levulose on the keeping quality*

| Particulars | Purity coefficient | Percentage of reducing sugar on dry matter | Percentage of moisture on dry matter under 75 per cent relative humidity and after a period of 10 days |
|---|---|---|---|
| Bazaar sugar 75 gm. + 300 c.c. of water boiled down to jaggery | 99·0 | 0·50 | 0·79 |
| Bazaar sugar 75 gm. + 1·5 gm. each of dextrose and levulose in 300 c.c. of water boiled to jaggery as in (1) | 93·8 | 6·23 | 4·57 |
| Bazaar sugar 75 gm.+3·0 gm. each of dextrose and levulose in 300 c.c. of water treated as before | 88·3 | 10·5 | 8·15 |

The effect of varying the amounts of reducing sugar only in the jaggery on its keeping quality was then studied (1) with white sugar solution by changing its reaction by the addition of small amount of acid or alkali, and (2) with cane juice by boiling it down to jaggery before and after the addition of lime. The results are given below.

TABLE II

*Effect of different amounts of reducing sugars on the keeping quality (starting with white sugar solution)*

| Particulars of treatment (1) | Purity co-efficient (2) | Reducing sugar (3) | Percentage of moisture on dry matter after a period of 3 weeks | |
|---|---|---|---|---|
| | | | 60 per cent relative humidity (4) | 80 per cent relative humidity (5) |
| 75 gm. of sugar + 300 c.c. of water, boiled to jaggery consistency | 97·2 | 0·50 | 1·51 | 2·36 |
| 75 gm. of sugar + 300 c.c. of water + 1 drop of strong acetic acid, boiled as above | 95·5 | 2·30 | 1·50 | 4·86 |
| 75 gm. of sugar + 300 c.c. of water + 3 drops of strong acetic acid, boiled as usual | 89·6 | 7·50 | 3·22 | 12·57 |
| 75 gm. sugar + 300 c.c. of water + 3 drops of 10 per cent sodium hydroxide | 98·7 | Traces | 0·83 | 1·41 |

TABLE—III

*The effect of reducing sugar on the keeping quality (starting with cane juice)*

| Particulars | Percentage of reducing sugar | Percentage of moisture on dry matter during a period of 3 weeks under 80 per cent relative humidity |
|---|---|---|
| Test. I | | |
| 750 c.c. of juice, boiled down to jaggery | 14·08 | 15·32 |
| 750 c.c. of juice, limed to litmus neutrality before concentration | 8·10 | 11·10 |
| 750 c.c. of juice overlimed before concentration | 5·09 | 9·83 |
| Test. II | | |
| 750 c.c. of juice, boiled down to jaggery | 19·35 | 19·25 |
| 750 c.c. of juice limed to litmus neutrality before concentration | 13·09 | 14·82 |
| 750 c.c. of juice overlimed before concentration | 10·86 | 13·24 |

The above data furnish strong evidence to the conclusion that one of the majorfactors that govern the keeping quality is the reducing sugar content.

*Effect of salts*

A series of experiments on similar lines to the above were carried out to determine the effect of various salts - particularly the chlorides and sulphates of sodium, potassium, and calcium on the keeping quality of jaggery.

TABLE IV

*Effect of increasing amounts of sodium chloride*

| Particulars of treatment | Purity co-efficient | Percentage of reducing sugar | Percentage of moisture on dry matter during a period of 3 weeks | |
|---|---|---|---|---|
| | | | 75 per cent relative humidity | 100 per cent relative humidity |
| Bazaar sugar 75 gm. + 300 c.c. of water, boiled and solidified | 98·4 | 0·84 | 1·27 | 25·7 |
| 75 gm. sugar + 0·37 gm. of sodium chloride + 300 c.c. of water, boiled as before | 97·6 | 1·23 | 4·50 | 35·4 |
| 75 gm. sugar + 0·75 gm. of sodium chloride + 300 c.c. of water boiled as before | 97·3 | 1·38 | 7·45 | 41·7 |
| 75 gm. sugar + 1·5 gm. of sodium chloride + 300 c.c. of water, boiled as before | 96·0 | 1·45 | 11·67 | 48·9 |

TABLE V

*Effect of increasing amounts of potassium chloride*

| Particulars of treatment | Purity co-efficient | Percentage of reducing sugar | Percentage of moisture on dry matter during a period of three weeks | |
|---|---|---|---|---|
| | | | 60 per cent relative humidity | 80 per cent relative humidity |
| 75 gm. of sugar + 300 c.c. of water, boiled and solidified | 98·8 | 0·59 | *Nil* | *Nil* |
| 75 gm. sugar + ·37 gm. of potassium chloride + 300 c.c. of water, boiled as before | 98·8 | 0·69 | 1·25 | 5·35 |
| 75 gm. sugar + ·75 gm. of potassium chloride + 300 c.c. of water, boiled as before | 98·6 | .. | 1·34 | 7·89 |
| 75 gm. sugar + 1·5 gm. of potassium chloride + 300 c.c. of water, boiled as before | 97·7 | 0·69 | 1·11 | 13·69 |

TABLE VI

*Effect of increasing amounts of calcium chloride*

| Particulars of treatment | Purity co-efficient | Percentage of reducing sugar | Percentage of moisture on dry matter | |
|---|---|---|---|---|
| | | | 60 per cent relative humidity | 80 per cent relative humidity |
| (a) 75 gm. sugar dissolved in 300 c.c. of water, boiled and solidified | 98·2 | 0·42 | *Nil* | 2·19 |
| (b) 75 gm. sugar and ·37 gm. of calcium chloride dissolved in 300 c.c. of water, boiled as before | 96·5 | 1·97 | 0·89 | 5·30 |
| (c) 75 gm. sugar and ·75 gm. of calcium chloride dissolved in 300 c.c. of water, boiled as before | 95·6 | 1·94 | 0·80 | 6·77 |
| (d) 75 gm. sugar and 1·5 gm. of calcium chloride dissolved in 300 c.c. of water, boiled as before | 94·4 | 1·95 | 2·71 | 11·45 |

TABLE VII

*Effect of sodium sulphate*

| Particulars of treatment | Purity co-efficient | Percentage of reducing sugar | Percentage of moisture on dry matter | |
|---|---|---|---|---|
| | | | 60 per cent relative humidity | 80 per cent relative humidity |
| (a) 75 gm. of sugar + 300 c.c. water, boiled and solidified | 99·7 | 0·55 | 0·98 | 2·12 |
| (b) 75 gm. of sugar + ·37 gm. of sodium sulphate, boiled as before | 99·1 | 0·37 | 0·95 | 3·24 |
| (c) 75 gm. of sugar + ·75 gm. of sodium sulphate, boiled as before | . . | 0·41 | 0·79 | 4·77 |
| (d) 75 gm. of sugar + 1·5 gm. of sodium sulphate, boiled as before | 97·8 | 0·47 | 0·56 | 8·11 |

TABLE VIII

*Effect of potassium sulphate*

| Particulars of treatment | Purity co-efficient | Percentage of reducing sugar | Percentage of moisture on dry matter | |
|---|---|---|---|---|
| | | | 60 per cent relative humidity | 80 per cent relative humidity |
| (a) 75 gm. of sugar + 300 c.c. of water, boiled and solidified | 97·8 | . . | *Nil* | 0·32 |
| (b) 75 gm. of sugar + 0·37 gm. of potassium sulphate dissolved in 300 c.c. of water, boiled as before | 97·2 | . . | *Nil* | 1·14 |
| (c) 75 gm. of sugar + 0·75 gm. of potassium sulphate dissolved in 300 c.c. of water, boiled as before | 97·3 | . . | *Nil* | 1·20 |
| (d) 75 gm. of sugar + 1·5 gm. of potassium sulphate dissolved in 300 c.c. of water, boiled as before | 95·5 | . . | *Nil* | 1·32 |

TABLE IX

*Effect of calcium sulphate*

| Particulars of treatment | Purity co-efficient | Percentage of reducing sugar | Percentage of moisture on dry matter | |
|---|---|---|---|---|
| | | | 60 per cent relative humidity | 80 per cent relative humidity |
| (a) 75 gm. of sugar dissolved in 300 c.c. of water, boiled and solidified | 99·7 | 0·47 | 0·25 | 1·12 |
| (b) 75 gm. of sugar dissolved in 300 c.c. of water, + 0·37 gm. of calcium sulphate | 99·1 | 0·57 | 0·53 | 1·61 |
| (c) 75 gm. of sugar dissolved in 300 c.c. of water, + 0·75 gm. of calcium sulphate boiled as before | 98·2 | 0·72 | 0·67 | 2·27 |
| (d) 75 gm. of sugar + 300 c.c. water + 1·5 gm. calcium sulphate, boiled as before | 97·5 | 0·74 | 0·87 | 2·11 |

*Effects of the chlorides of sodium, potassium and calcium compared*

The chlorides of each of these elements were added in quantities sufficient to supply 0·5 gm. of chlorine in each case.

TABLE X

*Comparison of the effects of chlorides of sodium potassium and calcium*

| Particulars of the experiment | Purity co-efficient | Percentage of reducing sugar | Percentage of moisture on dry matter | |
|---|---|---|---|---|
| | | | 60 per cent relative humidity | 80 per cent relative humidity |
| 75 gm. of sugar dissolved in 300 c.c. of water, boiled and solidified | 99·4 | 0·47 | 0·04 | 0·70 |
| 75 gm. of sugar + 0·82 gm. of sodium chloride dissolved in 300 c.c. of water, boiled and solidified | 98·0 | 0·65 | 2·20 | 8·08 |
| 75 gm. of sugar + 1·05 gm. of potassium chloride dissolved in 300 c.c. of water, boiled as before | 98·1 | 0·54 | 0·58 | 7·25 |
| 75 gm. of sugar + 0·82 gm. of calcium chloride dissolved in 300 c.c. of water boiled as before | 96·2 | 2·05 | 1·92 | 7·49 |

*Effect of sulphates of sodium, potassium and calcium*

The sulphates of the different metals were added to supply 0·5 gm. of $SO_3$ per 75 gm. of sugar.

TABLE XI

*Effect of sulphates of sodium, potassium and calcium*

| Particulars of treatment | Purity co-efficient | Percentage of reducing sugar | Percentage of moisture on dry matter | |
|---|---|---|---|---|
| | | | 60 per cent relative humidity | 80 per cent relative humidity |
| 75 gm. of sugar + 300 c.c. of water, boiled and solidified | 99·1 | 0·45 | 0·41 | 1·06 |
| 75 gm. of sugar + 0·9 gm. of sodium sulphate dissolved in 300 c.c. of water, boiled as before | 98·1 | 0·48 | 0·35 | 4·62 |
| 75 gm. of sugar + 1·1 gm. of potassium sulphate dissolved in 300 c.c. of water, boiled as before | 97·2 | 0·73 | 0·31 | 1·60 |
| 75 gm. of sugar + 0·9 gm. of calcium sulphate dissolved in 300 c.c. of water, boiled as before | 97·9 | 0·67 | 0·45 | 1·27 |

It will be seen that each of the chloride samples has absorbed high amounts of moisture under 80 per cent relative humidity. As regards sulphates, the sulphates of potassium and calcium have caused the absorption of only a little more moisture than the control. Sodium sulphate sample on the other hand has absorbed fairly large amounts though the moisture absorbed is only slightly more than half of that for sodium chloride.

In the boiling trials conducted in the laboratory as above, perfect control of the experimental conditions could not be secured. For example the period of boiling in these tests varied by a few minutes (5 to 10 minutes) and the temperature at which the change was struck varied by a degree on either side. To determine how far these small variations would affect the accuracy of the observations noted above, further experiments were conducted, varying the duration of boiling only.

TABLE XII

*The effect of small variations in the period of boiling and striking temperature on the composition and keeping quality of jaggeries, prepared from pure sugar solutions*

| Particulars of treatment | Period of boiling | Final striking temperature | Purity | Percentage of reducing sugar | Percentage of moisture on dry matter | |
|---|---|---|---|---|---|---|
| | | | | | 60 per cent relative humidity | 80 per cent relative humidity |
| | H. M. | | | | | |
| 75 gm. of bazaar sugar + 300 c.c. of water, boiled and solidified | 1—20 | 122°C. | 99·4 | 0·38 | 0·61 | 1·32 |
| Do. | 1—35 | 123°C. | 99·5 | 0·54 | 0·56 | 1·55 |
| Do. | 1—35 | 123°C. | 99·5 | 0·54 | 0·69 | 1·41 |
| Do. | 1—39 | 121°C. | 98·7 | 0·54 | 0·37 | 1·16 |
| Do. | 1—45 | 122°C. | 99·1 | 0·79 | 0·38 | 1·14 |
| Do. | 4— 0 | 123°C. | 97·6 | 1·43 | 0·86 | 2·69 |

It will be seen that the variations observed in the moisture contents of the above samples fall within rather narrow limits, showing thereby that the differences noted previously between samples under various treatments are real and not due to experimental error.

In the experiments quoted above, the line of attack has been to add directly to sugar solutions of the same strength known amounts of various salts, to prepare jaggeries out of them and to compare these different products as to their keeping qualities. Additional evidence was sought to be obtained on the question by adopting a different method of attack, viz. a study of the comparative behaviour of cane and cocoanut jaggeries.

Cane jaggeries ordinarily contain more glucose and less chlorides than cocoanut jaggeries and a study of the keeping qualities of these jaggeries revealed that in spite of their low glucose content the cocoanut jaggeries absorbed as much moisture as the cane jaggeries as shown below:

TABLE XIII

*Comparison of the composition and keeping quality of cane and cocoanut jaggeries*

| | Particulars | Percentage of sucrose | Percentage of glucose | Purity coefficient | Percentage of chlorine | Percentage of moisture on dry matter 75 per cent relative humidity |
|---|---|---|---|---|---|---|
| I | Cream jaggery : Cane—Poovan variety | 81·34 | 7·90 | 86·86 | 0·525 | 10·57 |
| I | Cream jaggery : Cocoanut | 84·24 | 3·44 | 91·66 | 0·850 | 9·82 |
| II | Poovan ordinary jaggery | .. | 15·63 | .. | 0·415 | 14·80 |
| II | Cream jaggery : Cocoanut | .. | 4·09 | .. | 1·110 | 14·50 |

The above results show that the chlorides do play no less an important role than glucose in regard to its effect on keeping quality.

*Effect of gums*

The effect of the so-called gums of sugarcane products which include protein, gums and pectins were next investigated and this was studied in two ways. Firstly, a sample of ordinary cane jaggery was dissolved in water to give a concentration of roughly 50 per cent total solids and the gums were precipitated from this solution by means of 95 per cent alcohol. The gums were filtered off and the filtrate was boiled down into jaggery. The jaggery so prepared was analysed and its keeping quality compared with that of the original jaggery.

Secondly, the gums separated as above were washed thoroughly with 80 per cent alcohol, dried and mixed with bazaar white sugar. This was dissolved in water and boiled down into jaggery in the usual way. The composition and keeping quality of this product were compared with those of the product from white sugar. The results are presented below :

TABLE XIV

*Effect of the 'gums' separated from jaggery on keeping quality*

| Particulars | Percentage of sucrose | Percentage of glucose | Percentage of gums | Percentage of chlorine | Percentage of moisture on dry matter 75 per cent relative humidity |
|---|---|---|---|---|---|
| Cane jaggery from Co 360 | 83·22 | 8·03 | 0·86 | 0·417 | 10·15 |
| The above jaggery dissolved in an equal quantity of water, boiled again into jaggery | 76·50 | 10·69 | 1·56 | 0·417 | 12·20 |
| Gums removed by precipitation with 95 per cent alcohol, filtrate boiled down into jaggery | 79·32 | 10·69 | 0·05 | 0·490 | 11·34 |
| Bazaar sugar 75 gm. dissolved in 100 c.c. of water, made into jaggery | 94·79 | 0·33 | .. | .. | 0·23 |
| Sugar 75 gm. + 1·85 gm. of gums dissolved in 100 c.c. of water, boiled into jaggery | 93·17 | 0·88 | .. | .. | 0·97 |

The results strongly indicate that the adverse effect of gums on the keeping quality of jaggery is comparatively small while that of glucose and chlorides is very pronounced indeed.

The study of the problem under question was continued by carrying out investigations involving a different line of attack.

Jaggeries from both cane and cocoanut were subjected to various treatments such as clarification with activated carbon and kieselgurh, and extraction with various organic solvents resulting in the removal of one or more of their ingredients. The jaggeries so treated were analyzed and their moisture absorbing capacities estimated in the usual way.

In the following experiment, a sample of cane jaggery was successively extracted at room temperature with (a) 95 per cent ethyl alcohol saturated with sodium chloride, (b) with 95 per cent ethyl alcohol, and (c) again with 95 per cent ethyl alcohol. The original jaggery and the different products obtained after extraction were analyzed for various constituents and their moisture absorbing capacities at 75 per cent relative humidity were also determined. The data are given below :

TABLE XV

*Composition and moisture absorbing power of jaggery before and after extraction with 95 per cent ethyl alcohol saturated with sodium chloride and with pure 95 per cent alcohol*

| Heads of analysis and other particulars | Original jaggery | After extraction with 95 per cent alcohol saturated with NaCl (a) | (a) Extracted with 95 per cent alcohol (b) | (b) Extracted with 95 per cent alcohol (c) |
|---|---|---|---|---|
| | | Percentage on dry basis | | |
| Sucrose | 82·11 | 82·64 | 88·08 | .. |
| Glucose | 11·60 | 5·50 | 1·38 | .. |
| Chlorine | 0·553 | 0·543 | 0·366 | 0·086 |
| Nitrogen | 0·039 | 0·043 | 0·040 | 0·042 |
| Gums | 0·755 | 0·698 | 0·700 | .. |
| Moisture absorbed under 75 per cent relative humidity calculated on dry matter | 16·27 | 11·74 | 6·42 | 4·62 |
| Percentage decrease in moisture absorbed | .. | 27·84 | 60·53 | 71·60 |

It will be seen that as a result of extraction with 95 per cent ethyl alcohol saturated with sodium chloride, the jaggery lost about 50 per cent of glucose but very little of chlorine, nitrogen and gums and there is a noticeable reduction in the percentage of moisture absorbed. This indicates that the improvement in keeping quality exhibited by the extracted material is possibly due to the partial removal of glucose. When the above product is again subjected to repeated extraction with pure 95 per cent ethyl alcohol, a further marked loss in the glucose percentage and an appreciable reduction in the chlorine content are noticed; but no change in the nitrogen or gums percentages is observed. The improvement in the keeping quality has been very marked, thus demonstrating the adverse effect of glucose and chlorine on the keeping quality of jaggery.

The effect of the partial removal of nitrogenous substances and gums from jaggery without change in the glucose and chlorine percentages was studied as follows:

Cane and palmyra jaggeries were dissolved in water, clarified with activated carbon and reboiled into jaggery. In another experiment, the reconverted jaggery was extracted with 95 per cent ethyl alcohol. These different products were analyzed and their keeping qualities compared in the usual manner. The data are presented below:

TABLE XVI

*Analysis and keeping quality of a sample of cane jaggery before and after treatment with activated carbon*

| Heads of analysis | Original jaggery (a) | (a) After clarification with activated carbon (b) | (a) Dissolved in water and reboiled into jaggery (c) |
|---|---|---|---|
| | Percentage on dry basis | | |
| Sucrose | 88·1 | 89·1 | 84·9 |
| Glucose | 7·71 | 8·09 | 9·35 |
| Ash | 2·045 | 2·380 | 2·065 |
| Chlorine | 0·251 | 0·391 | 0·259 |
| Gums | 0·367 | 0·061 | 0·321 |
| Nitrogen | 0·059 | 0·038 | 0·061 |
| Moisture absorbed from an atmosphere of 75 per cent relative humidity | 9·80 | 11·15 | 10·95 |

In spite of the great reduction in the gums fraction and a perceptible reduction in the nitrogen percentage, sample (b) has not shown any improvement in keeping quality; on the other hand, a deterioration in quality is noticed possibly due to its higher chlorine content.

TABLE XVII

*Palmyra jaggery before and after treatment*

| Heads of analysis | Palmyra jaggery (a) | (a) Treated with activated carbon and kieselgurh (b) | (b) Extracted with 95 per cent alcohol (c) | (a) Extracted with 95 per cent alcohol (d) |
|---|---|---|---|---|
| | | Percentage on dry basis | | |
| Sucrose | 88·12 | 90·88 | 93·83 | 88·82 |
| Glucose | 3·04 | 3·40 | 1·43 | 1·72 |
| Ash | 5·146 | 3·211 | 2·117 | 4·641 |
| Chlorine | 0·748 | 0·741 | 0·417 | 0·583 |
| Gums | 0·533 | 0·205 | 0·182 | 0·487 |
| Nitrogen | 0·173 | 0·133 | 0·100 | 0·159 |
| Moisture absorbed from an atmosphere of 75 per cent relative humidity period from 22-11-44 to 5-12-44 | 12·36 | 11·69 | 7·03 | 5·18 |

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The above results furnish additional evidence to show that it is the glucose and chlorine fraction and not the gums and nitrogenous fraction in jaggery that harms its keeping quality. Comparing (a) and (b). it will be seen that there is practically no change in the glucose and chlorine contents; but more than 60 per cent of the gums and about 25 per cent of the nitrogen have been removed; yet no improvement in keeping quality is visible. Again on comparing (a) and (d) one will notice a considerable reduction in the glucose and chlorine percentages and practically little change in the gums and nitrogenous fractions. The improvement in the keeping quality of (d) over that of (a) is marked. The inference appears to be obvious.

## Discussion of results

The harmful influence of chlorides of sodium, potassium and calcium and the sulphate of sodium and that of reducing sugars has been demonstrated by straight experiments in which the above substances were individually added to pure sugar solutions, the solutions thus made were subsequently converted into jaggeries and the products finally obtained were compared for their moisture absorbing capacities with reference to their chemical composition. Confirmatory evidence in support of the above conclusion was obtained by experiments which involved the removal of particular constituent or constituents from jaggeries by treating the latter with suitable reagents including organic solvents and activated carbon and subsequent comparison of the treated product with the original jaggery for their keeping qualities. Thus extraction of a sample of jaggery in the cold with 95 per cent ethyl alcohol saturated with sodium chloride removed an appreciable portion of reducing sugars but practically little of the chloride, gums or nitrogenous fraction from the jaggery and as a result the extracted product revealed an appreciable improvement in keeping quality. Subsequent extraction of the treated production with 95 per cent ethyl alcohol effected a further reduction in the reducing sugar content and a considerable reduction in the chlorine content, but again very little of the gums and nitrogenous matter was removed. As expected a further improvement in the keeping quality was noticed.

On the other hand, treatment of the sample of jaggery with activated carbon leading to considerable reduction of the gums and nitrogenous substances but without any effect on the reducing sugars or chloride did not produce any improvement in the keeping quality of the jaggery.

A comparative study of the composition and keeping quality of typical samples of palmyra(cocoanut) jaggery and cane jaggery has supplied further evidence in support of the above conclusion. Palmyra or cocoanut jaggery is characterized ordinarily by low glucose and high chlorine contents, whereas cane jaggery possesses in general a higher glucose and a lower chlorine content. In spite of the low glucose percentage, cocoanut jaggery has been found to absorb moisture to as high a level as the sample of cane jaggery possibly due to its high chlorine content.

The above conclusion is however quite contradictory to the one arrived at by Varahalu, viz. that organic non-sugars exercise a very potent influence on the keeping quality of jaggery whereas glucose and chlorides play only a very minor role in this respect. It may be mentioned in this connection that his experiments were confined to mere observations of the setting quality of sugar solutions as influenced by the addition of varying amounts of glucose and chlorides to the former. He did not carry the study further to compare the moisture absorbing capacities of the different products obtained as a result of the various treatments.

It is pertinent and of interest to record here the observations made regarding the behaviour of cane juices clarified with activated carbon but unlimed and that of juices limed but not treated with activated carbon. It is well known that cane juices treated with activated carbon boil smoothly without frothing up to the striking point, presumably due to the removal of non-sugar colloids as a result of the activated carbon treatment. Some of these juices however do not set readily at the striking point and the jaggeries obtained are soft. On the other hand cane juices clarified with lime alone give rise to considerable frothing and the boiling is not smooth. They however set readily when concentrated to the proper consistency and the jaggeries are hard. These observations suggest that the removal of non-sugar organic colloids from the juice, as in the case of carbon-treatment, do not seem to help in the setting of the final thick syrup and in the production of a hard jaggery,

and contrariwise that the non-removal of the organic colloids, as in the treatment of the juice with lime only, does not appear to prevent the final syrup from setting readily and giving rise to hard jaggery. When it is remembered that activated carbon treatment removes from the juice a considerable portion of the colloids but little of the glucose and that mere lime treatment greatly minimises inversion of sucrose into glucose but effects little change in the colloidal content of the juice, the conclusion appears to be inevitable that it is mainly the glucose and the glucose decomposition products that interfere with the setting of the final syrup and the quality of the resultant jaggery.

## Summary


It is generally known that keeping quality of jaggery is intimately associated with its chemical composition ; but the chief constituent or constituents which control this charater has been a matter of controversy.

Evidence has been furnished in this paper to prove that reducing sugars and chlorides play a very important role on the moisture-absorbing capacity of jaggery and that organic non-sugars including the so-called 'gums' and nitrogenous substances exert only a comparatively minor effect.

Experiments leading to the above conclusion included the following set of experiments :

(a) Jaggeries were prepared on a laboratory scale from white sugar solutions to which various amounts of the chlorides and sulphates of sodium, potassium and calcium, of dextrose and levulose and of the so-called 'gums' separated from cane jaggery had been added. The moisture-absorbing capacities of the above products showed that the chlorides among the salts studied and dextrose, levulose and the reducing sugars increase the moisture-absorbing capacity of the jaggery to a considerable extent.

The so-called 'gums' appeared to produce only a comparatively small effect.

(b) Jaggery samples were successively extracted with 95 per cent ethyl alcohol in the cold, resulting in considerable reduction of the reducing sugars and chlorine contents without however any appreciable effect on the 'gums' and nitrogenous fractions. These extracted products showed a marked improvement in keeping quality as a result of the treatment.

On the other hand jaggery solutions on clarification with activated carbon and kieselgurh lose a considerable proportion of the gums and a fair portion of the nitrogen, but very little of the reducing sugars or the chlorides. These clarified solutions on conversion into solid jaggery showed, however, no improvement in the keeping quality.

(c) A comparison of the composition and keeping qualities of typical cane and cocoanut jaggeries furnished additional evidence in support of the above conclusion.


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# SOME OBSERVATIONS ON THE WATER RELATIONS OF SUGAR CANE PLANT IN NORTH BIHAR

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(With four text figures)

SUGAR-CANE is essentially a tropical plant. In Bihar the cane growing tract entirely lies in the sub-tropical region. This cane tract is sub-divided into two by the intervening river Ganges. The sub-tract north of Ganges, popularly known as North Bihar, is more intensively cultivated with cane than the region south of the river. Soil of North Bihar, is rich alluvium widely varying in texture from place to place. At places it is underlain with pockets of sand. During the monsoon season the downward movement of rain water is quick and in the process soil and sub-soil both become completely saturated with moisture. This happens because of the calcareous nature of the soil. The presence of lime reduces the cohesive force amongst the particles and in consequence not only the penetration is quick but also the field saturation capacity of the soil is high. The plant roots spread out in a wide circumference and show deep penetration both in the soil and the sub-soil. This enables the crops to subsist on the stored soil moisture during the non-rainy periods and realize the maximum benefit out of the precipitation received during the monsoon season. Thus it is the ease with which soil is able to deliver water to the imbibing surfaces of the plant roots that the cane crop is grown without artificial irrigation in North Bihar. The annual precipitation in this cane growing region is about 45 in. At the foot of the hills it is more abundant than in the region close to the Ganges. The major portion of the rainfall is received in the monsoon period. Cane crop occupies the land from 9-11 months and this period may broadly be divided into three seasons, namely, summer, monsoon and winter. In North-Bihar, because of the unirrigated nature of the crop, hot weather forms the critical stage in the growth cycle of the crop. Under such environmental conditions the relationship between available soil moisture and plant growth is not quite a simple one. Growth effected is not only determined by the distribution of rainfall but also depends upon the nature of the critical or stress periods. which precede, intervene or succeed this precipitation. The object of the present contribution is a preliminary attempt to elucidate the relation of the cane plant to soil moisture under such environmental conditions.

## Historical

The first systematic attempt to determine soil-water-growth relationship was made by Briggs and Shantz [1912 and 1914]. Briefly their studies conclusively showed that the lowest limit of available soil moisture for uninterrupted growth of plants is the wilting coefficient of the soil. Soil moisture above this limit is readily available both for metabolic and transpiration processes of the plant. At or below wilting coefficient water in the soil is not readily available for transpiration purposes and plants enter their quescent state of wilting [Luthra and Raheja, 1933], when slow rate of water absorption continues to some extent till complete desiccation occurs, the plants during the drying stage simply acting as the medium for the transference of water from the soil to air. Briggs and Shantz [1912] observed from their experimental evidence that plants differed but slightly in their ability to deplete the moisture content of any given soil. Alway [1913] found that under normal conditions plants were able to reduce the moisture content of the soil to the hygroscopic coefficient. This, however, does not imply that plants can utilize for growth the small amount of water available between the limits of the wilting and the hygroscopic coefficients of the soil. On the contrary this portion of water has a very high value for the maintenance of life under conditions of extreme aridity. Briggs and Shantz [1916] also concluded from their studies that crop plants widely differed in their relative water requirements. Maximov [1929] confirming the above conclusion further stated that drought resistant plants do not necessarily have a low water requirement. Their drought resistance is due to a multiplicity of morphological and physiological characteristics. From extensive studies on water



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balance of drought resistant plants, wild and cultivated, he concluded that physiologically drought resistant plants are better capable of maintaining their water balance under conditions of drought stress than the less resistant ones and that they invariably transpire at a much faster rate under conditions of abundant water supply. His conclusions accord with the theoretical analysis given by Huber [1923] for the maintenance of water balance of plants. With this brief survey of the fundamental work on water relations of plants we proceed to describe the investigations.

## Investigations and methods

The undermentioned aspects of the problem of water balance were studied:

1. Water content and diurnal moisture deficit in cane leaves
2. Rate of water loss during the course of wilting
3. Relative rate of transpiration from varieties during the hot weather stage of the cane plant
4. Relative rate of transpiration from varieties during the maturition stage of the crop

The technique and the methods employed for the study of the investigations are briefly stated below.

### *Determination of water content and leaf moisture deficit*

Five sugar cane varieties sharply contrasting in their physiological nature, especially in respect of their drought resistant capacities as evidenced by visual observations in the field, were selected for the above studies. These had veen grown in the same field for experimental work. Leaf samples were drawn at two-hourly intervals. For each of the samples of a given variety five standard (transverse mark) leaves from five of the stalks were removed and were immediately transferred to weighed bottles which were capped air tight. For each of the varities three such samples on every occasion were removed. All the fifteen sample bottles were removed to the laboratory where these were weighed. The leaf samples were dried at 95°C. in an electrically operated air oven to a constant weight. Leaf moisture in every case was calculated on original fresh weight of the sample. The sampling for the hot weather was done in the month of May on three clear days. Five such estimations in the months of July and August were made for the nonsoon period. For the cold weather again three similar estimations were recorded in November. With a view to elucidate the varietal differences in each of the seasons mean values for each of the varieties have been worked out to compare the seasonal effect on the leaf moisture variations amongst the various varieties.

### *Rate of water loss during the course of wilting*

Ten varieties similarly differing in their physiological traits, including the five varieties taken for the above experiments, were studied to determine the rate of water loss during the course of wilting of cut shoots. Immediately after cutting each of the shoots was weighted in a glass jar, and transported to the laboratory close by, the actual time of weighing being noted in every case. The weight of the shoot was recorded up to the second place of decimal. The period between the first weighing in the field and the second in the laboratory has been termed the 'period of conditioning'. So long as the shoots were small and could be contained in a glass container they were carried to the laboratory as such. Later on, however, it was not possible to do so and the shoots were brought to the laboratory without the container. Because of this difference in treatment of the shoots the differences noticed during the 'period of conditioning' for the various seasons have not been compared. Subsequent weighings hereafter were taken regularly at half hour intervals. In all 8 to 10 weighings in each case were recorded. At the end of the period the dry weights of the shoots were determined. Therefrom, on dry weight basis, the rate of water loss for each of the intervals was calculated. These determinations were made during each of the three seasons and the results given in the test are the mean values of the three readings. The experiments were carried out in May for the hot weather, in July and August for the monsoon season and in November for the cold weather.

### *Relative rate of transpiration from varieties during hot and cold weathers*

Uniformly grown plants of nine varieties, including the five taken for the previous studies, were subjected to experiment. The pots had a size one foot square in cross section and two feet in depth.

ı mid-April earthenware jars of about 600-700 c.c. capacity, with open mouth of about one inch in iameter, were fixed for making up the loss in soil moisture due to transpiration. To do away with the ırface evaporation soil surface of the pots was waxed. Prior to the sealing of the soil the soil ıoisture of the pots was brought to field saturation capacity of the soil. Daily weighings for deter-ining the transpiration loss were recorded each day in the morning at about 8 A.M. The loss of ater was made good in each case through the earthenware jars. Five plants of each variety were ıder experiment. Weighments were begun in early May and continued for five weeks. Height easurements of the mother shoots indicated that plants made small growth because of the intense mospheric aridity prevailing then. At the close of five weeks' period dry matter of the actively anspiring foliage was separately determined from the rest of the plant and on the basis of foliage eight, transpiration ratios were worked out for every plant. The roots of plants were washed with e needed care over a fine wire gauze of 225 meshes to a square inch. After washing the roots they ere cleaned of all extraneous matter and their dry weight was determined. From the dry weights the foliage and the roots, foliage root ratios were worked out and the results have been interpreted relation to transpiration ratios of varieties under experiment.

Similarly treated plants were employed for the study of the transpiration rates of varieties during e cold weather months. In order to determine the transpiration intensities of the varieties leaf eas of the varieties were determined at the beginning and at the close of the experiment. The anspiring area was determined by the procedure described by Khanna [1931]. Briefly stated it nsisted of multiplying leaf length with the leaf breadth at the widest point and leaf area factor termined for most of these varieties, *i.e.* 0·7005. Since both surfaces of the leaf transpire, twice e area of leaves was taken as the transpiring area of the foliage. Dry matter of the foliage and roots as determined at the close of the experiment for the purpose already stated for the hot weather ries.

## Experimental results

Mean values of leaf moisture for the various varieties, on different dates, at different hours of e day, have been set down in Table I and graphed in Fig. 1a.

TABLE I

*Per cent leaf moisture data obtained during hot weather*

| Time/Date | 7.0 A.M. | 9.0 A.M. | 11.0 A.M. | 1.0 P.M. | 3.0 P.M. | 5.0 P.M. |
|---|---|---|---|---|---|---|
| | | | *Variety—Co213* | | | |
| [illegible] | 75·50 | 73·50 | 72·20 | 72·00 | 71·87 | 71·70 |
| [illegible] | 77·38 | 76·63 | 74·54 | 73·86 | 73·58 | 73·48 |
| [illegible] | 75·11 | 73·59 | 72·95 | 72·06 | 71·85 | 71·64 |
| …an | 76·00 | 74·57 | 73·23 | 72·64 | 72·43 | 72·27 |
| | | | *Variety—Co313* | | | |
| [illegible] | 75·30 | 73·80 | 71·20 | 70·25 | 70·70 | 70·50 |
| [illegible] | 76·83 | 74·02 | 73·49 | 71·51 | 71·07 | 71·36 |
| [illegible] | 72·52 | 71·64 | 72·70 | 69·24 | 69·31 | 68·68 |
| …an | 74·88 | 73·15 | 72·46 | 70·33 | 70·36 | 70·18 |
| | | | *Variety—Co210* | | | |
| [illegible] | 74·50 | 73·70 | 73·20 | 72·60 | 71·20 | 73·20 |
| [illegible] | 68·39 | 78·17 | 75·27 | 74·27 | 71·85 | 72·72 |
| [illegible] | 76·29 | 74·46 | 72·67 | 71·42 | 70·04 | 71·42 |
| …n | 76·39 | 75·44 | 73·71 | 72·76 | 71·03 | 72·45 |

TABLE I—*contd.*

*Per cent leaf moisture data obtained during hot weather*—contd.

| Time/Date | 7.0 A.M. | 9.0 A.M. | 11.0 A.M. | 1.0 P.M. | 3.0 P.M. | 5.0 P.M. |
|---|---|---|---|---|---|---|
| | | | *Variety—Co285* | | | |
| 9/5 | 72·70 | 71·20 | 69·70 | 68·80 | 68·90 | 69·30 |
| 16/5 | 74·10 | 74·50 | 73·91 | 72·90 | 72·39 | 72·70 |
| 26/5 | 72·95 | 71·61 | 70·47 | 69·01 | 68·36 | 69·54 |
| *Mean* | 73·25 | 72·44 | 71·36 | 70·24 | 69·85 | 70·51 |
| | | | *Variety—Co331* | | | |
| 9/5 | 71·60 | 70·80 | 70·70 | 70·10 | 70·80 | 71·60 |
| 16/5 | 73·90 | 72·98 | 72·25 | 72·09 | 72·98 | 73·73 |
| 26/5 | 72·60 | 71·54 | 70·78 | 69·87 | 69·15 | 69·54 |
| *Mean* | 72·70 | 71·77 | 71·24 | 70·69 | 70·98 | 71·62 |

A perusal of the results indicates that as the day advanced leaves tended to exhibit saturation deficit. During the hot weather usually leaf moisture did not show a recovery till 3.0 P.M. In the case of Co213 and Co313 a further drop was observed at 5.0 P.M. while varieties Co210 and Co285 had higher water content at 5.0 P.M. than at the preceding hour. Variety Co331 began to make up its water deficit before 3.0 P.M. The mean maximum saturation deficit, on the original leaf water content, at 7.0 A.M., in the decreasing order in the varieties, was Co210, Co213, Co313, Co285 and Co331 (Fig. 1a). The analysis of the data is given in Table II.

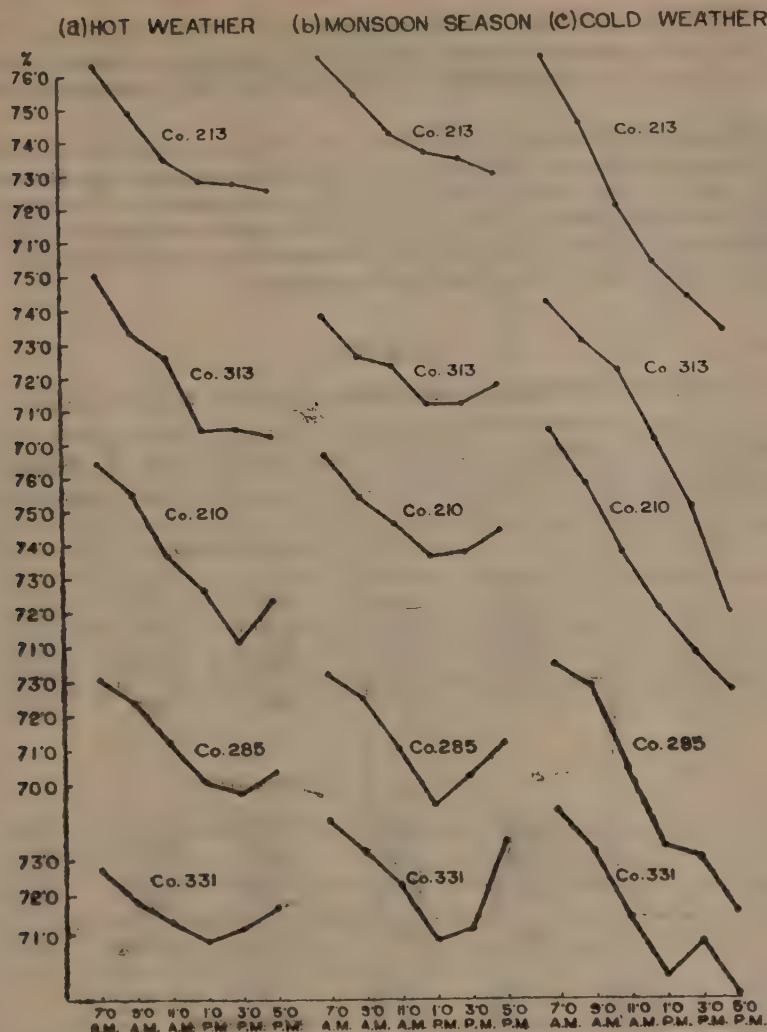


FIG. 1. Periodic variations in leaf moisture

TABLE II

*Analysis of variance—hot weather series*

| Due to | Degree of freedom | Sum of squares | Mean variance | $F^1/F^2$ |
|---|---|---|---|---|
| Varieties (V) | 4 | 91·8903 | 22·9726 | 1·285 |
| Dates (D) | 2 | 106·5397 | 53·2698 | 2·979* |
| Two-Hourly Fluctuations (T) | 5 | 157·1305 | 31·4261 | 1·758† |
| Interactions : | | | | |
| V × D | 8 | 10·8194 | .. | .. |
| V × T | 20 | 27·0639 | .. | .. |
| D × T | 10 | 5·4713 | .. | .. |
| *Residual error* | 40 | 715·1941 | 17·87985 | .. |
| *Total* | 89 | | | |

* Significant at 10 per cent † Significant at 20 per cent

Two-hourly fluctuations exhibited significant differences at 20 per cent level of significance. Still wider differences were apparent for mean values of leaf moisture on different dates which were significant at 10 per cent level of significance. The various first order interactions were not significant.

During the monsoon period, except variety Co213, the foliage of all the other varieties exhibited the maximum saturation deficit at 1.0 P.M. (Fig. 1b). This deficit was made up in the case of varieties Co285 and Co331 after 1.0 P.M., so that leaves had higher water content at 3.0 P.M. and 5.0 P.M. respectively. In the case of varieties Co313 and Co210 the deficit continued to exist till 3.0 P.M. Later the deficit was made up partially by 5.0 P.M. In general in the monsoon period varieties exhibited 2 per cent less water deficit than during the dry weather.

### Table III

*Two-hourly fluctuations in leaf moisture during the monsoon period*

| Time/Date | 7.0 A.M. | 9.0 A.M. | 11.0 A.M. | 1.0 P.M. | 3.0 P.M. | 5.0 P.M. |
|---|---|---|---|---|---|---|
| | | | *Variety—Co213* | | | |
| 2/7 | 75·95 | 75·18 | 74·34 | 73·81 | 74·36 | 73·03 |
| 14/7 | 74·69 | 74·00 | 73·45 | 73·00 | 72·55 | 71·77 |
| 4/8 | 74·73 | 74·08 | 72·13 | 71·89 | 72·02 | 72·73 |
| 18/8 | 78·96 | 75·50 | 73·34 | 73·24 | 73·00 | 73·04 |
| 27/8 | 76·52 | 76·81 | 76·33 | 74·85 | 73·40 | 73·08 |
| *Mean* | 76·17 | 75·11 | 73·92 | 73·38 | 73·07 | 72·73 |
| | | | *Variety—Co313* | | | |
| 2/7 | 72·29 | 71·85 | 70·68 | 68·87 | 69·00 | 69·86 |
| 14/7 | 71·84 | 70·34 | 70·18 | 69·72 | 70·54 | 69·54 |
| 4/8 | 74·08 | 73·32 | 72·90 | 72·11 | 70·46 | 71·34 |
| 18/8 | 73·89 | 72·96 | 72·28 | 71·91 | 71·91 | 74·20 |
| 27/8 | 75·75 | 75·43 | 74·56 | 72·51 | 73·14 | 73·06 |
| *Mean* | 73·57 | 72·38 | 72·12 | 71·02 | 71·01 | 71·06 |
| | | | *Variety—Co210* | | | |
| 2/7 | 76·88 | 77·10 | 76·36 | 74·75 | 75·30 | 76·68 |
| 14/7 | 76·61 | 73·27 | 73·07 | 72·61 | 72·92 | 73·08 |
| 4/8 | 75·39 | 75·60 | 73·43 | 72·65 | 72·16 | 72·64 |
| 18/8 | 77·25 | 75·67 | 75·23 | 73·88 | 74·05 | 76·19 |
| 27/8 | 74·21 | 73·74 | 72·97 | 68·08 | 69·65 | 69·79 |
| *Mean* | 73·29 | 72·56 | 71·15 | 69·48 | 70·36 | 71·30 |
| | | | *Variety—Co331* | | | |
| 2/7 | 76·59 | 75·96 | 74·53 | 70·84 | 70·03 | 75·61 |
| 14/7 | 72·20 | 70·34 | 71·42 | 70·33 | 70·31 | 71·68 |
| 4/8 | 74·50 | 72·38 | 71·83 | 71·19 | 71·63 | 71·79 |
| 18/8 | 73·11 | 72·94 | 72·13 | 70·99 | 73·07 | 72·98 |
| 27/8 | 75·02 | 74·52 | 71·66 | 69·91 | 71·78 | 73·31 |
| *Mean* | 74·08 | 73·23 | 72·31 | 70·63 | 71·36 | 73·47 |

TABLE IV

*Analysis of variance—monsoon series*

| Due to | Degree of freedom | Sum of squares | Mean variance | $F^1/F^2$ |
|---|---|---|---|---|
| Dates (D) . . . . . . . . . . | 4 | 76·119 | 19·02975 | 11·876* |
| Varieties (V) . . . . . . . . . | 4 | 238·047 | 59·51175 | 37·1368* |
| Intervals (I) . . . . . . . . . | 5 | 175·67 | 35·13 | 21·92* |
| Interactions : | | | | |
| D × V . . . . . . . . . . | 16 | 79·472 | 4·967 | 3·0996* |
| D × I . . . . . . . . . . | 20 | 22·318 | .. | .. |
| D × I . . . . . . . . . . | 20 | 19·504 | .. | .. |
| *Residual error* . . . . . . . . . | 80 | 128·202 | 1·6025 | .. |

* Significant at 1 per cent level

The analysis variance of the data, given in Table III, was carried out (Table IV) which indicates significant differences amongst varieties in their mean leaf water content irrespective of the two-hourly intervals and dates of estimation of leaf water content. Similarly significant differences were observed amongst various dates irrespective of the effect of two-hourly fluctuations and the varieties. The interaction between varieties and dates was also significant, so that on different dates varieties showed different water content. On the whole the two-hourly intervals exhibited significant differences.

In the cold weather a progressive deficit in leaf water content was noticed as the day advanced. The rate of decrease from hour to hour was very much pronounced as compared to the preceding two seasons (Table V, Fig. 1C). This is evident from Table VI in which the analysis of variance of the data is given :

TABLE V

*Diurnal variation in leaf moisture during the cold weather*

| Dates/Time | 7.0 P.M. | 9.0 P.M. | 11.0 A.M. | 1.0 P.M. | 3.0 P.M. | 5.0 P.M. |
|---|---|---|---|---|---|---|
| | | | *Variety—Co213* | | | |
| 6/11 . . . . . . | 79·29 | 76·40 | 74·10 | 71·30 | 69·40 | 68·65 |
| 23/11 . . . . . . | 74·77 | 72·68 | 69·11 | 67·76 | 67·66 | 67·11 |
| 28/11 . . . . . . | 75·40 | 73·56 | 72·00 | 71·24 | 70·44 | 68·79 |
| *Mean* . . . . . . | 76·25 | 74·21 | 71·74 | 70·10 | 69·17 | 68·18 |
| | | | *Variety—Co313* | | | |
| 6/11 . . . . . . | 73·38 | 72·19 | 71·86 | 69·80 | 68·18 | 64·24 |
| 23/11 . . . . . . | 74·05 | 72·98 | 72·75 | 70·39 | 70·34 | 66·50 |
| 28/11 . . . . . . | 74·39 | 73·29 | 71·47 | 69·90 | 66·40 | 64·11 |
| *Mean* . . . . . . | 73·94 | 72·82 | 72·03 | 70·03 | 68·31 | 64·59 |
| | | | *Variety—Co210* | | | |
| 6/11 . . . . . . | 77·09 | 74·98 | 72·97 | 70·56 | 70·35 | 69·95 |
| 23/11 . . . . . . | 78·38 | 77·27 | 74·80 | 72·85 | 70·12 | 67·59 |
| 28/11 . . . . . . | 76·30 | 74·80 | 73·53 | 72·91 | 69·09 | 68·26 |
| *Mean* . . . . . . | 77·26 | 75·68 | 73·73 | 72·11 | 69·85 | 68·72 |

TABLE V—*contd.*

*Diurnal variation in leaf moisture during the cold weather*—contd.

| Dates Time | 7.0 P.M. | 9.0 P.M. | 11.0 A.M. | 1.0 P.M. | 3.0 P.M. | 5.0 P.M. |
|---|---|---|---|---|---|---|
| | | | *Variety—Co285* | | | |
| 6/11 . . . . . . | 74·67 | 73·70 | 71·60 | 70·45 | 68·85 | 66·24 |
| 23/11 . . . . . . | 76·00 | 75·32 | 73·07 | 69·07 | 69·90 | 67·97 |
| 28/11 . . . . . . | 73·92 | 72·67 | 70·00 | 68·43 | 68·67 | 68·15 |
| *Mean* . . . . . . | 74·54 | 73·90 | 71·56 | 69·32 | 69·01 | 67·45 |
| | | | *Variety—Co331* | | | |
| 6/11 . . . . . . | 72·00 | 70·83 | 68·00 | 67·30 | 69·50 | 69·23 |
| 23/11 . . . . . . | 74·20 | 73·19 | 71·12 | 69·50 | 70·12 | 66·72 |
| 28/11 . . . . . . | 73·83 | 72·72 | 71·71 | 69·00 | 69·30 | 68·26 |
| *Mean* . . . . . . | 73·34 | 72·24 | 70·28 | 68·60 | 69·67 | 68·07 |
| | | | *Variety—Co299* | | | |
| 6/11 . . . . . . | 74·53 | 73·64 | 71·44 | 68·41 | 67·28 | 64·15 |
| 23/11 . . . . . . | 71·92 | 68·70 | 67·20 | 65·10 | 64·91 | 62·90 |
| 28/11 . . . . . . | 72·20 | 68·92 | 65·80 | 64·00 | 63·30 | 60·98 |
| *Mean* . . . . . . | 72·88 | 70·42 | 68·15 | 65·83 | 65·16 | 62·68 |
| | | | *Variety—Co281* | | | |
| 6/11 . . . . . . | 76·78 | 74·29 | 71·70 | 68·20 | 70·30 | 67·53 |
| 23/11 . . . . . . | 76·92 | 73·45 | 71·45 | 69·00 | 70·80 | 66·34 |
| 28/11 . . . . . . | 76·85 | 73·87 | 71·58 | 68·30 | 70·55 | 66·94 |
| *Mean* . . . . . . | 76·85 | 73·87 | 71·58 | 68·60 | 70·55 | 66·94 |
| | | | *Variety—Co356* | | | |
| 6/11 . . . . . . | 77·24 | 76·02 | 75·23 | 74·76 | 72·44 | 89·83 |
| 23/11 . . . . . . | 76·60 | 74·24 | 72·90 | 71·85 | 69·80 | 66·40 |
| 28/11 . . . . . . | 78·10 | 75·50 | 74·94 | 73·39 | 69·40 | 68·22 |
| *Mean* . . . . . . | 77·31 | 75·25 | 74·36 | 73·33 | 70·57 | 68·15 |
| | | | *Variety—Co326* | | | |
| 6/11 . . . . . . | 76·70 | 74·36 | 72·33 | 70·22 | 69·88 | 70·78 |
| 23/11 . . . . . . | 76·34 | 75·24 | 73·25 | 72·94 | 70·23 | 69·72 |
| 28/11 . . . . . . | 74·50 | 72·10 | 69·55 | 68·20 | 68·53 | 66·10 |
| *Mean* . . . . . . | 75·85 | 73·90 | 71·71 | 70·12 | 69·55 | 68·87 |

TABLE VI

*Analysis of variance—cold weather series*

| Due to | Degree of freedom | Sum of squares | Mean variance | $F^1/F^2$ |
|---|---|---|---|---|
| Dates (D) | 2 | 23·625 | 11·8125 | 5·921* |
| Intervals (I) | 5 | 1261·850 | 252·37 | 126·50* |
| Varieties (V) | 8 | 399·011 | 49·876 | 25·00* |
| *Residual error* | 146 | 291·2907 | 1·995 | .. |
| *Total* | 161 | | | |

* Significant at 1 per cent level

The analysis exhibited highly significant differences amongst the two-hourly fluctuations. Similarly differences in the mean leaf moisture content during the day amongst the varieties were also observed to be highly significant. Considering all the varieties under study during this stage Co281 showed the maximum deficit of 12·89 per cent and Co331 least deficit of 7·19 per cent over the initial water content of varieties at 7·00 A.M. In the last column of Table VII the order of earliness in maturity of varieties has been shown. It will be observed that during the cold weather early varieties, namely Co299, Co281 and Co313, exhibited higher water deficit than medium-early or late canes.

*Rate of water loss during the course of wilting*

Darwin [1901], Darwin and Pertz [1912] and Knight [1917] noticed that on severing a leaf from the stem and allowing it to wilt, a temporary opening of stomata prior to closure following upon wilting occurred. Knight stated that the time that elapsed between seering the leaf from the plant and the opening of stomata varies considerably with different plants. Transpiration within certain limits followed the course of the opening and closing of stomata on leaves. Studies carried out on different varieties of cane during the hot weather exhibited this sequence in the rate of transpiration under low transpiration conditions of the laboratory (Fig. 2). At first there was a progressive fall with time to a minimum, depending upon the variety following which the rate of transpiration rapidly rose, but soon after there occurred a decline in the curve of all the varieties. It may be mentioned that some varieties exhibited greater loss during the process of wilting than others. The maximum loss was sustained by variety B. 6308 of all the varieties under test.

The results of experiments conducted during the monsoon are presented graphically in Fig. 3 of the text. Marked tendencies in the course of changes during the process of wilting were rather irregular in all the varieties and the behaviour completely differed from the previous period. In the monsoon season it appears the foliage do not have a greater reserve of water which on wilting may be available for transpirational loss. Combined experiments on changes in stomatal aperture of wilting plants and their rate of transpiration conducted by Knight (loc. cit.) indicated, a rough correlation with the magnitude of the increase of stomatal aperture. It is interesting to speculate on the changes which occur respectively to the stomata during the monsoon and the cold weather. Knight could observe no correlation between the temperature of the air and the magnitude of the accompanying increase in transpiration rate from the leaf surface. At the same time he found a distinct relationship between the temperature during the experiment and the length of the interval between the commencement of wilting and the occurrence of the maximum transpiration rate which approximately varied inversely with temperature. Evidently other factors than the temperature factor were responsible for the loss of unregulated transpiration during the process of wilting. Water content of leaf is a factor of importance in the process was clearly shown by Knight. During monsoon the plants have ample supplies of water at their disposal and they seldom suffer from shortage. The atmospheric relative humidity also remains high. The foliage are adopted to such conditions. They maintain water balance without suffering an acute water deficit. It is, therefore, that during the monsoon season the maximum deficit exhibited by any of the varieties is small, compared to the deficit either in the hot weather or cold season.

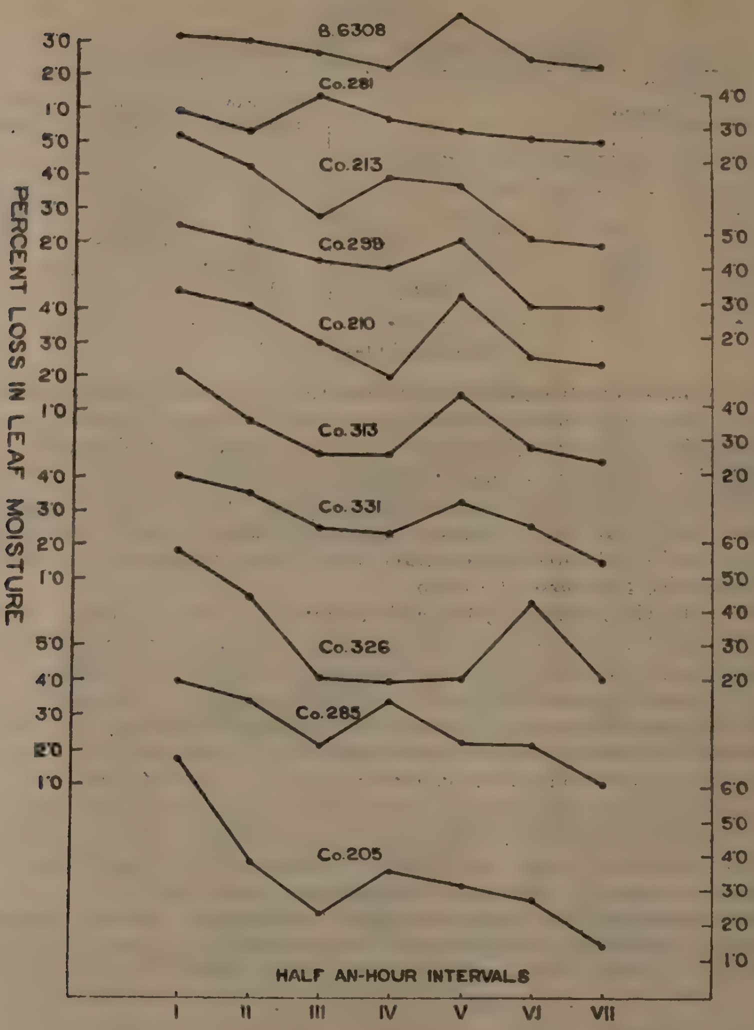


FIG. 2. The rate of water loss during the course of wilting : the hot weather series

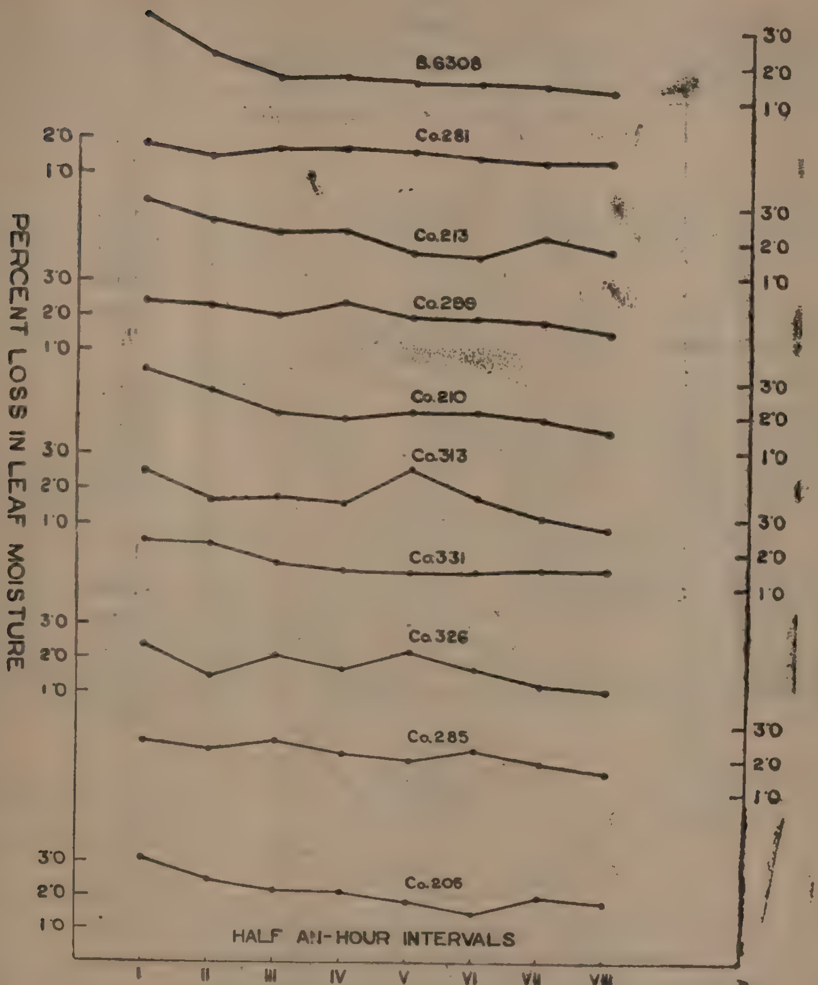


FIG. 3. The rate of water loss during the course of wilting: the monsoon series

So long as the plant experiences little shortage of water the whole regulating mechanism remains inactive and the march of transpiration passively follows that of the meteorological factors. No sooner the leaf cells experience a deficiency in water supply the turgor is lost and a tension equivalent to many atmospheres arises in the cells. This in turn is transmitted to the vessels. These, it is presumed, are compressed as they give up their water to the parenchyma of the leaf. This suction, developed in wilting leaves due to to the cohesive power of the water permeating the plant, is transmitted to all parts and acts as a powerful regulator of transpiration from the leaves [Maximov, 1929]. During the monsoon season, owing to the mild environment, the suction pressure in the leaf cells is not very great. If any deficit occurs, with a slight suction pressure equivalent to a few atmospheres, the loss is made good through the channel of vessels by the roots which have ample supplies of easily available water at their disposal. On the other hand in the hot weather or in the cold season the soil moisture is not so readily available with the result that a greater water deficit in the leaves is created during the afternoon hours. During the cold weather this deficit is greater because of larger transpiring area of the foliage of the crop than of the as yet comparatively smaller plants during the hot weather.

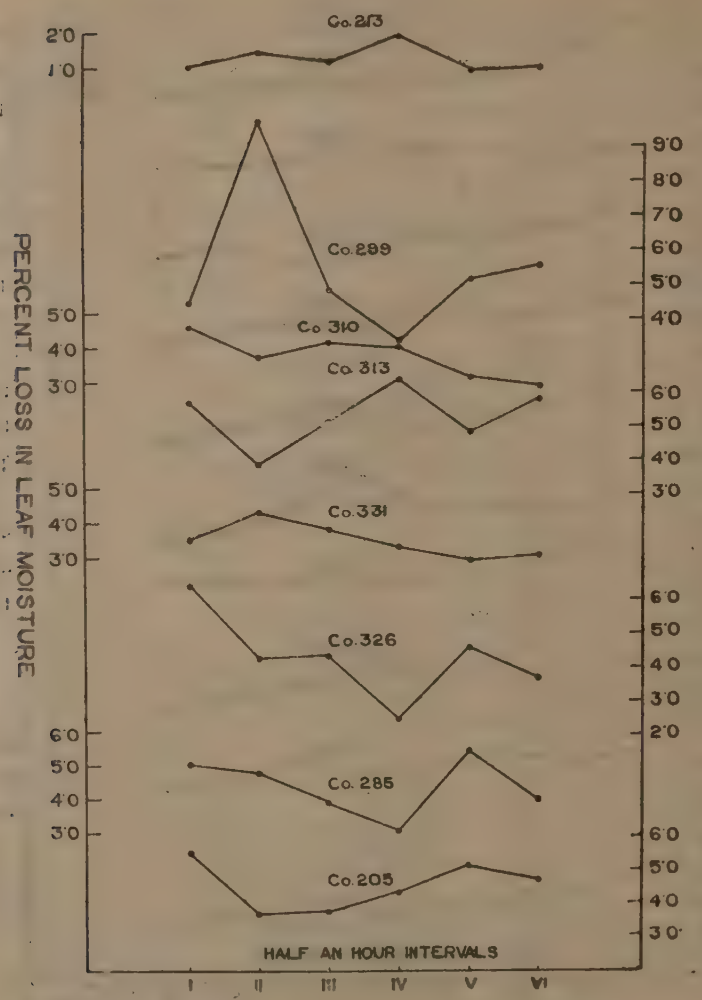


FIG. 4. The rate of water loss during the course of wilting : the cold weather series

Since during the monsoon period the leaves do not manifest high degree of moisture deficit, the available water for loss during the process of wilting is small and the leaves, when artificially wilted after severing them from the plant, did not exhibit the marked tendencies during the course of wilting. In fact the loss experienced from one interval of half hour to another was so small that abrupt rise and fall might not have been clearly exhibited. In the cold weather in spite of the leaves exhibiting high degree of moisture deficit, and thus high suction tension equivalent to a many atmospheres, other conditions upset the regulatory function of the stomata, and the deficit could not be made up in leaves till 5 P.M. Luthra and Chima [1937] while working on cotton noticed that during the month of November the transpiration-regulatory function of stomata was lost. Assuming that that happens with sugar cane stomata also, it is evident that in spite of the high suction developed within the vessels of the plant the deficit in leaf moisture is not made up towards the evening in the cold season, as it could be made up during the hot weather or monsoon period (Fig. 1).

*Relative rate of transpiration from varieties in relation to environment*

Before proceeding to give detailed data for transpiration it appears appropriate to give the data on foliage and root development for both are separate entities when absorption and transpiration are considered individually (Huber, loc. cit.). The mean dry matter weights of foliage and roots of the five plants of each of the varieties and the ratios between the two are given in Table VII.

TABLE VII

*Foliage/Root ratios and relative transpiration ratios : Hot weather studies—dry weight in gm.*

| Particulars | Varieties. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Co285 | Co281 | Co299 | Co210 | Co213 | Co331 | Co326 | Co313 | Co205 |
| Foliage—gm. | 40·40 | 41·57 | 41·03 | 54·77 | 48·76 | 49·42 | 50·60 | 32·32 | 48·10 |
| Roots—gm. | 10·48 | 10·61 | 10·78 | 18·62 | 17·34 | 19·47 | 20·64 | 13·74 | 24·91 |
| Mean water loss per day—gm. | 231·65 | 285·20 | 142·78 | 266·18 | 389·10 | 399·31 | 480·70 | 237·22 | 513·22 |
| Foliage/Root ratios | 4·20 | 3·92 | 3·81 | 2·94 | 2·80 | 2·50 | 2·45 | 2·35 | 1·93 |
| Relative transpiration ratios | 5·26 | 6·86 | 3·48 | 4·86 | 7·98 | 8·08 | 9·50 | 7·34 | 10·67 |

Coefficient of correlation between foliage/root and relative transpiration ratios —0·68±0·1787

It will be observed that generally varieties which have high foliage/root ratios have low relative transpiration ratios. Statistical examination of the data revealed a fairly high significant coefficient of correlation between the two factors.

During the senescent phase of the cane crop when transpiration rate principally due to less intense environment, is low the results indicated similar trends. The data are presented in Table VIII.

TABLE VIII

*Foliage/root ratios and relative transpiration of varieties during the senescen phaset of the crop—dry matter in gm.*

| Particulars | Varieties | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Co285 | Co326 | Co213 | Co299 | Co313 | Co281 | Co331 | Co205 | Co210 |
| Foliage wt.—gm. | 187·52 | 276·01 | 203·90 | 185·15 | 258·50 | 126·44 | 248·04 | 171·38 | 218·78 |
| Roots wt. ,, | 76·13 | 115·24 | 84·91 | 86·05 | 119·94 | 59·14 | 127·74 | 96·96 | 125·18 |
| Foliage/root ratios | 2·47 | 2·40 | 2·40 | 2·18 | 2·15 | 2·14 | 1·94 | 1·76 | 1·74 |
| Relative transpiration ratios | 4·44 | 3·66 | 7·26 | 4·05 | 6·46 | 6·15 | 6·02 | 5·25 | 7·26 |

Coefficient of correlation between foliage/root ratios and the relative transpiration ratios .. —0·722±0·1072 (significant at 5 per cent).

It is evident from the high value of the coefficient of correlation that the extent of root system like the foliage, plays an important part in regulating transpiration of the plant.

Maximov (loc. cit.) while explaining the mechanism of regulation of transpiration stated that investigations of Lloyd [1912], Livingston and Brown [1912], Muenscher [1915] and Knight [1922] had shown that stomatal aperture and transpiration did not show consistent interrelationship. In sugar cane Kuyper [1915] observed that the maximum rate of transpiration generally reached after the stomata had begun to close so that the transpiration rate was independent of the stomatal behaviour under the conditions of his experiments. Haines [1935] stated, that the water content of the leaf is one of the principal factors controlling the transpiration rate, the operating factor being the Pressure deficit which he defined as the difference between the pressure in the conducting tract and the pressure at the leaf surface. According to Miller [1938], these pressure deficits alone apparently cannot reduce transpiration by their effects upon the vapour pressure at the leaf

cell surfaces but must also cause an increase in the resistance to the flow of water through the protoplasts of the cells of the leaf. Two of the factors that apparently may greatly influence the degree of incipient drying in the leaf and thus influence its rate of transpiration are the leaf surface and the nature of the root system. Under the environmental conditions, when atmospheric aridity manifested its influence, the coefficients of correlation between foliage-root ratio and the relative transpiration ratios were fairly high and significant. Evidently foliage and roots in concert with each other play a significant part in regulating transpiration through the plant.

*Rate of transpiration during the successive months of the maturition stage of the crop—*

It is natural enough that the varieties should show an increased rate of water loss during the summer and active growing season. During the maturition stage when the plants enter into a state of senescence, bringing growth almost to a stand still, it appeared interesting to study the behaviour of varieties in respect of the transpiration rate month after month. The results (Table IX) indicate that relative transpiration ratio and the transpiration intensity decreased as the season advanced and varieties matured. Graphic representation of the data further revealed that early varieties, namely, Co299 and Co313 exhibited a more rapid decrease in the transpiration loss than the other varieties under experiment. These varieties within a period of one month i.e. in November showed a decrease of 20 per cent as compared to Co281, a medium early variety, which depressed the rate of water loss by about 10 per cent only. Other varieties maintained transpiration rate equal to their October values. In December early varieties had depressed their rate of loss to about 50 per cent while the mid-season ones kept up to about 70 per cent and higher of the October value. In January though all varieties indicated decrease the magnitude of depression was not as great as in the preceding month. Evidently the various varieties exhibited different behaviour as the season advanced. If environment were the factor mainly responsible then all the varieties should have exhibited equal depression in the rate of water loss as the season advanced and became cooler and cooler month by month. Obviously other factors intervened to cause a difference in the degree of depression in the rate of transpiration exhibited by varieties in the various months.

TABLE VIII

*Relative transpiration ratios and transpiration intensities of varieties during senescent phase of cane crop*

| Varieties | Months | Relative transpiration ratios: On foliage dry weght basis | Relative transpiration ratios: per cent of October value | Transpiration on foliage area basis | Intensities per cent of October value |
|---|---|---|---|---|---|
| Co299 | October | 4·05 | 100·0 | 0·155 | 100·0 |
| | November | 3·22 | 79·5 | 0·124 | 80·0 |
| | December | 2·16 | 53·3 | 0·083 | 53·7 |
| | January | 2·02 | 49·0 | 0·078 | 51·0 |
| Co313 | October | 6·46 | 100·0 | 0·211 | 110·0 |
| | November | 5·12 | 79·3 | 0·167 | 79·1 |
| | December | 3·38 | 52·3 | 0·110 | 52·0 |
| | January | 2·48 | 38·2 | 0·095 | 45·0 |
| Co281 | October | 6·51 | 100·0 | 0·147 | 100·0 |
| | November | 5·61 | 86·2 | 0·134 | 91·1 |
| | December | 4·31 | 62·2 | 0·103 | 70·1 |
| | January | 3·61 | 56·6 | 0·083 | 56·5 |

## TABLE VIII

*Relative transpiration ratios and transpiration intensities of varieties during senescent phase of cane crop*

| Varieties | Months | Relative transpiration ratios | | Transpiration on foliage area basis | Intensities per cent of October value |
|---|---|---|---|---|---|
| | | On foliage dry weight basis | per cent of October value | | |
| Co285 | October | 4·44 | 100·0 | 0·122 | 100·0 |
| | November | ·37 | 98·4 | 0·119 | 97·6 |
| | December | 3·06 | 68·9 | 0·083 | 64·3 |
| | January | 2·75 | 61·9 | 0·075 | 58·1 |
| Co331 | October | 6·02 | 100·0 | 0·141 | 100·0 |
| | November | 5·08 | 84·4 | 0·133 | 97·8 |
| | December | 4·23 | 70·2 | 0·102 | 72·3 |
| | January | 4·19 | 69·2 | 0·098 | 69·5 |
| Co210 | October | 7·26 | 100·0 | 0·136 | 100·0 |
| | November | 7·13 | 98·2 | 0·134 | 98·5 |
| | December | 5·68 | 78·2 | 0·107 | 79·4 |
| | January | 5·39 | 74·2 | 0·101 | 75·0 |
| Co205 | October | 5·25 | 100·0 | 0·149 | 100·0 |
| | November | 5·20 | 99·0 | 0·149 | 100·0 |
| | December | 4·15 | 79·0 | 0·118 | 79·2 |
| | January | 3·73 | 71·0 | 0·107 | 71·8 |
| Co213 | October | 4·41 | 100·0 | 0·152 | 100·0 |
| | November | 4·71 | 106·8 | 0·163 | 107·3 |
| | December | 3·65 | 82·8 | 0·126 | 82·9 |
| | January | 3·48 | 78·9 | 0·120 | 78·9 |
| Co326 | October | 3·66 | 100·0 | 0·128 | 100·0 |
| | November | 4·05 | 110·7 | 0·142 | 110·0 |
| | December | 3·40 | 92·9 | 0·119 | 91·5 |
| | January | 3·24 | 88·5 | 0·114 | 88·4 |

## GENERAL DISCUSSION.

In the words of Leake [1943], the capacity of any climate to support plant life depends on two factors, that which may be termed the energy level, of which a partial measure is the temperature and the moisture level of which the measure is rainfall. Failure in a crop is due to the fact that morphologically or physiologically it is not adapted to the range of these two levels occuring in the locality. However, the grower may manage to change the moisture level to suit the plant. But he is unable to change the energy level very materially. The water balance of the plant at any moment is 'the resultant of the interplay of all the factors, both internal and external, affecting its water balance'. Virtually the leaf moisture content at any given time during the day is determined by the rates of transpiration and absorption from the plant. When the former tends to be more rapid than the absorption from the soil, a moisture deficit in the leaf occurs, the degree of which depends upon the aridity of external environment. In our results (Tables I, II and III) the degree of moisture deficit during the mid-day hours in the hot weather and cold months was much greater than in the monsoon months. Further it was noticed that during the cold season when plant enters upon its senescent phase all the products of metabolism are not utilized for growth but a major portion of them is stored as carbohydrates. The rate of accumulation of sucrose in the cane plant thus increases. Some of the varieties store up sugar at a much faster rate than others and are fit to be crushed early. It was observed that not only the degree of saturation deficit increased very considerably in the autumn

months than that in the hot weather but early maturing varieties exhibited greater saturation deficit as compared with the mid-season or late canes. Besides, it was noticed that as season advanced the early or medium-early maturing varieties depressed their rate of transpiration much more than mid-season or late canes (Fig. 4). It is evident that an internal factor other than the general structure of the leaf or the external environment was affecting the saturation deficit and transpiration rate. Drabble and Drabble [1907] noticed that the concentration of sap must vary over a wide range in order that any appreciable influence may be exerted on transpiration rate. The difference in the concentration of sucrose content in the cell sap of the plants of early and mid-season and late varieties varies between 3 and 5 per cent. These differences had been sufficient to depress the transpiration rate by 20 per cent in the November month.

It was, however, noticed that Co285, an early maturing cane, maintained its transpiration rate in November equal to that in October. This exceptional behaviour may be explained on the basis of its drought resistant nature [Khanna and Venkatraman, 1929]. It has been shown by various workers such as Dunn [1933], Dexter, Tottingham and Garber [1930] that xerophytic plants posses higher content of hydrophyllic colloids which under conditions of drought develop high imbibition pressure and, therefore, retain high water content in the leaf and this was so in spite of the high concentration of cell sap in the stem which should cause greater water deficit in the leaves.

Weaver and Clements [1929] have stated, 'A complete scientific understanding of relationship between the soil and crop cannot be obtained until the mechanism is understood by which the soil and plant are brought into favourable relationship, i.e. root system'. Khanna [1934] has recognized three distinct types of root systems in sugar cane, namely, (a) mesophytic, (b) semi-xerophytic and (c) xerophytic. The classification is based primarily on the nature of vertical and horizontal spread of the root system in the soil. The varieties with mesophytic type of root system are less resistant to drought owing to more lateral spread, so that during the periods of drought the varieties suffer from low availability of water for maintaining water balance of the plant. During the hot weather and in the autumn months when the crop has to subsist on conserved moisture in the soil, the type of root system must play very significant part in the upkeep of leaf moisture, rate of transpiration, turgor, etc. A variety which is unable easily to adjust itself under these environmental conditions must of necessity fail. This conclusion is supported by the data on transpiration ratios and foliage/root ratios. Significant negative correlations were observed between the two entities under the summer and autumn conditions (Tables VII and VIII), the two stress periods in the environment of North Bihar.

## Summary

Investigations on the water relations of sugar cane plant under the unirrigated conditions of North Bihar were conducted for better comprehension of the functional response and suitability of the cane varieties to the environmental conditions.

Experimental evidence indicated that early varieties, namely, Co281, Co299, Co313 and Co356 exhibited a higher saturation deficit after the mid-day hours than either the mid season or late canes. Maximum deficit was indicated in the autumn months and minimum during the monsoon period. The course of changes in the rate of water loss from the wilting leaves during the hot weather was normal, i.e. initial fall was followed once by a rapid rise and then a slow decline; during the monsoon such changes were less conspicuous and in the cold weather they were irregular in all the varieties. Foliage/root ratios and the relative transpiration ratios of the varieties during the hot weather and the autumn months exhibited high significant correlationship. During the latter season a successive decrease, month by month, in the relative transpiration ratios and transpiration intensities was exhibited by all the varieties. The early maturing ones depressed the rate of water loss to about 50 per cent of their October value in the month of January, while others kept up to about 70 per cent or higher of the initial values in October. The importance of extensive semi-xerophytic root system of the varieties for North Bihar soils has been indicated. The exceptional behaviour of Co285 in decreasing its relative transpiration ratio in the manner of early varieties and still maintaining high water content in the foliage is attributed to its drought resistant nature.

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# THE RELATIVE EFFICIENCY OF WATER REQUIREMENTS IN RELATION TO MANURIAL TREATMENTS*

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Soil fertility is a critical factor limiting growth of plants. One of the basic essentials of any crop for successful growth and development is its nutrient requirements. It is not merely the application of one single element such as nitrogen and its effect that are required to be studied but the working out of a well balanced nutrient schedule is the primary need. This schedule should necessarily ameliorate or lessen the deficiencies of available plant nutrients, should produce apt physical changes in the soil base and should conduce to elaboration of nutrient salts in an assimilable form; otherwise the application of fertilizers is bound to be wasteful because of the failure to take the circumstances fully into account. This is specially true of nitrogen fertilizers as it is subject to more rapid depletion than others. It is the purpose of this note to demonstrate the effectiveness of the different manurial schedules, time of their application, form in which nitrogen should be applied and to express this effectiveness mathematically in terms of relative efficiency of water requirements.

There is available a mass of data bearing on the response of crops to application of fertilizers as measured by final harvest yields but there is generally a paucity of information on the effects of the application of fertilizers to soil on the several functional responses of plants. McCool [1928] showed that the application of potash and phosphoric acid resulted in an appreciable increase in the concentration of cell sap and that when phosphoric acid was used it had a tendency to bring about a reverse action. He also stated that leaves of plants dried out (wilted) more rapidly when grown on soils without fertilizers than on soils to which fertilizers had been added which difference he assumed to be due to differences in the concentration of cell sap. Leather [1912], Kiessalbach [1916] and Singh and Mehta [1938] have shown that transpiration ratios of crops are lowered by manurial treatment. Raheja [1934], besides confirming the above conclusions, observed that wheat crop manured with farm yard manure made more economical use of water than that manured with an equivalent dose of ammonium sulphate. Sethi [1936] reported that under conditions obtaining at Shahjehanpur optimum returns in cane yield were obtained with a considerably low water duty when nitrogen fertilizer was applied at the rate of 100 lb. per acre. Rege, Yaghoklar, Wagle, Apte and Kulkarni [1943] have investigated on a field scale, the water requirements of sugar cane crop in relation to manurial tretaments. They observed that the interaction between nitrogen application and water duty was significant, indicating the value of higher manuring with higher irrigation.

Leather [1907] and later on Davis [1918] pointed to the deficiency of phosphates in North Bihar soils and stressed the need of application of phosphoric acid as a fertilizer. Cliff [1931] concluded from the data of trials extending over three seasons, 1928-29 to 1930-31, that a dressing of 40 lb. nitrogen and 50 lb. phosphoric acid gave substantial and significant increase in yield in every case over the control series. The manures, however, were applied in two doses, one half at planting and the other half at earthing up of the crop, that is with the first break of the monsoon. These findings were further confirmed by Cliff [1937] and it was pointed out that with a normal crop of sann hemp (Crotolaria juncea), buried as green manure during the preceding monsoon and with one maund of double superphosphate applied at planting, the need for the first half dose (20 lb. of N and 25 lb. of P2O5) was obviated. Cliff, however, could not decide as to whether to apply the manure in one dose or in two half-dozes. Recently Yuen and Borden [1937] have shown that cane plant can rapidly absorb from the soil available nitrogen and the quantity of nitrogen absorbed is independent of the needs of plant which when absorbed beyond the requirements at the moment might be stored up and used for subsequent growth.

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* Read at the 1940 meeting of the Indian Science Congress Association.

## Methods and experimental scheme

The experiments hereinafter described were conducted in auto-irrigators. The method of determining water requirements in auto-irrigators has already been described by the authors [1937]. Manurial doses applied were calculated on the surface area basis of the containers and were applied as per scheme of experiments described later in the text. The manures to be applied at planting were spread on the surface and the soil worked up to a depth of 6 in.to thoroughly incorporate the manure within the zone in which the set was to be planted. The recording of water day by day supplied by auto-irrigation system was then taken up. The manuring at earthing was done through the system of auto-irrigation.

Two sets of experiments were conducted. The first set consisted of studies for determining the effect of the application of inorganic fertilizers in relation to relative efficiency of water requirements and the second related to the study of the effect of castor cake & super when it replaced Niciphos II in the ordinary dose recomemended by Cliff [1931]. Besides, the object of these experiments was also to determine if the total quantity of manure applied in one dose at planting was more beneficial than when applied in two half-doses, that is one half at planting and the remaining half at earthing up of the crop. The treatments in the first set consisted of various dozes of inorganic manures as shown in Table I.

### Table I

*Scheme of inorganic manurial series*

| Pot No. | Notation for treatment | Treatments per acre in Lbs. At planting N | $P_2O_5$ | $K_2O$ B | At earthing up N | $P_2O_5$ | $K_2O$ | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1-4 | A | *nil* | *nil* | *nil* | *nil* | *nil* | *nil* | Nitrogen was applied as ammonium sulphate; $P_2O_5$ as superphosphate and boron as boric Acid. |
| 5-8 | B | 40 | 50 | 0 0 | *nil* | *nil* | *nil* | |
| 9-12 | C | 20 | 25 | 0 0 | 20 | 25 | 0 | |
| 13-16 | D | 40 | 50 | 80 0 | .. | .. | .. | |
| 17-20 | E | 20 | 25 | 40 0 | 20 | 25 | 40 | |
| 21-24 | F | 40 | 50 | 80 0 | *nil* | *nil* | *nil* | |

Planting for this series was done as early as the middle of February and the shoots were visible on the soil surface within 18 to 20 days of planting in all the containers.

The treatments in the second set of experiments planted a fortnight later are given in Table II.

### Table II

*Scheme of organic versus inorganic fertilizer series*

| Pot. No. | Notation for treatment | Treatments per acre in Lbs. At planting | | At earthing up | | Remarks |
|---|---|---|---|---|---|---|
| | | | N | $P_2O_5$ | | N $P_2O_5$ |
| 1-4 | P | *nil* | *nil* | *nil* | *nil* | Niciphos II was selected as it has equal proportion of N and $P_2O_5$. |
| 5-10 | Q | 22 | 22 | 22 | 22 | |
| | | (Applied as Castor cake and super) | | | | |
| 11-14 | R | 44 | 44 | *nil* | *nil* | |
| | | (Applied as castor cake and super) | | | | |
| 15-18 | S | (As castor cake and super) | | (As niciphos II) | | |
| | | 22 | 22 | 22 | 22 | |
| 19-22 | T | (Applied as Niciphos II) | | | | |
| | | 44 | 44 | *nil* | *nil* | |
| 23-28 | U | (Applied as Niciphos II) | | | | |

In this case also the plants appeared above ground within 20 days of the planting. The growth of plants was normal in the containers in both the series which were harvested in early February next year when their dry weights were determined. Simultaneously the total amount of water expended by each of the plants was worked out. In the calculation of the relative water requirements under various treatments root-weights were not taken into account because these studies were conducted to conform to the manurial experiments in progress in the field where root-weights were not possible. The bearing of these results will be discussed in a later publication when confirmatory results from further experiments in the field have been obtained by the senior author.

## Experimental results

The results from the inorganic fertilizer series show (Table III) that in order of merit, the treatments, D,B,E,C, and F respectively indicate higher relative efficiency of water requirements as compared to the treatment A.

This evidently suggests that the application of fertilizers is beneficial in increasing the relative efficiency of water requirements.

Table III

*Relative efficiency of water requirements in the inorganic manure series*

| Serial No. | A<br>No manure (Control) | B<br>40 lb. N+50 lb. $P_2O_5$ in one dose at planting | C<br>40 lb. N+50 lb. $P_2O_5$ in two half dozes, each at planting and earthing | D<br>40 lb. N+50 lb. $P_2O_5$+80 lb. $K_2O$ at planting alone | E<br>20 lb. N+25 lb. $P_2O_5$+40 lb. $K_2O$ at planting and same at earthing | 40 lb. N+50 lb. $P_2O_5$+80 lb. $K_2O_5$+ 10 lb. boron at planting alone |
|---|---|---|---|---|---|---|
| I | 293·0 | 195·0 | 165·7 | 172·8 | 175·5 | 210·0 |
| II | 255·7 | 175·9 | 240·0 | 200·1 | 173·7 | 153·5 |
| III | 193·2 | 183·4 | 219·5 | 181·4 | .. | 216·7 |
| IV | 283·8 | 199·8 | 177·7 | 167·5 | 223·2 | 241·9 |
| *Mean* | 256·4 | 191·1 | 200·7 | 180·5 | 192·4 | 205·5 |
| S. E. of difference between two treatment means | | .. | .. | ±17·46 | .. | .. |
| Relative efficiency of water requirements | 1·000 | 1·342 | 1·278 | 1·421 | 1·333 | 1·248 |

A comparison of treatments D and B and treatments E and C brings out the fact that application of potash, whether it was applied in one dose at planting or in two half-doses, improves the relative efficiency of water requirements. The effect of boron, however, is to depress the efficiency of water requirements, as the comparison of the mean values for F against B, C, D and E indicates. It is also apparent from a comparative study of the mean values of treatments B and C and treatments D and E that the application of the fetilizers in two half-doses is not conducive to economical use of water by the plants.

In the organic versus inorganic manure series (Table IV) a comparison of treatments P against R, U, Q, T and S shows that manurial treatments in this experiment also increased the relative efficiency of water requirements. Therefore in general the experimental results of the first and the second series corroborate each other.

TABLE IV

*Relative efficiency of water requirements in the organic versus inorganic fertilizers series*

| Serial No. | P No manure (Control) | Q Castor cake+Super-22 lb. N +22 lb. $P_2O_5$ at planting and same at earthing up | R Castor cake+Super-44 lb. N+44 lb. $P_2O_5$ at planting alone | S Castor cake+Super 22 lb. N+22 lb. $P_2O_5$ at planting and Niciphos II-22 lb. N+22 lb. $P_2O_5$ at earthing | T Niciphos II-22 lb. N+22 lb. $P_2O_5$ at planting and same at earthing up | U Niciphos II-44 lb. N+44 lb. $P_2O_5$ at planting alone |
|---|---|---|---|---|---|---|
| I | 194·7 | 144·8 | 180·5 | 226·1 | 257·1 | 148·4 |
| II | 332·4 | 188·1 | 168·5 | 209·8 | 250·0 | 543·3* |
| III | 247·5 | 272·9 | 150·3 | 246·2 | 236·1 | 174·8 |
| IV | 244·4 | 299·1 | 178·7 | 232·1 | 187·4 | 155·7 |
| V | *nil* | *nil* | 146·5 | *nil* | *nil* | 185·2 |
| VI | *nil* | *nil* | 153·3 | *nil* | *nil* | 194·7 |
| *Mean* | 254·8 | 226·2 | 162·9 | 228·6 | 232·7 | 171·8 |
| S. E. of difference between two treatments means | | | | ±22·41 | .. | .. |
| Relative efficiency of water requirements | 1·000 | 1·016 | 1·411 | 1·005 | 0·892 | 1·338 |

Further study of mean values of different treatments shows that the single dose at planting is superior to the two half doses, applied half at planting and remaining half at earthing up, in both the organic and the inorganic schedules of manuring. This is evident from the comparison of treatments R and Q and treatments U and T. The organic schedule of manuring is also slightly better than the inorganic one under discussion (Compare mean values of treatments R and U and treatments Q and T).

The analysis of variance of the results as worked out for the first set of experiments is given in Table V.

TABLE V

*Analysis of variance : Inorganic manure series*

| — | Degrees of freedom | Sum of squares | Mean variance | Value of F Observed | Value of F Theoretical at P=0·05 |
|---|---|---|---|---|---|
| Treatments | 5 | 14442·22 | 2888·44 | 2·99 | 2·81 |
| Errors | 17 | 16429·96 | 966·47 | | |

From the analysis it is evident that differences amongst the treatments were significant at 5 per cent level of significance, lending further support to the conclusions reached above that manurial treatments gave higher efficiency of water requirements than no manure treatment. The analysis of variance of the data presented in Table IV, is given in Table VI.

TABLE VI

*Analysis of Variance* : Organic versus inorganic fertilizer series

| — | Degrees of freedom | Sum of squares | Mean variance | Value of F Observed | Value of F Theoretical at P=0·05 |
|---|---|---|---|---|---|
| **Total** | 26 | 64559·41 | | | |
| **Between treatment means** | 5 | 32921·008 | 6584·2016 | 4·36 | 4·04 |
| **Residual error** | 21 | 31638·402 | 1506·5906 | | |

For purposes of analysis figure 543·3 relating to U treatment (Table II) was rejected on account of its abnormality. The analysis indicates significant differences amongst the treatments. Full dose application of organic or inorganic schedule of manuring shows definite decrease in the absolute water requirements of the plants. The split up dose though apparently indicates a decrease, the difference between the control and treatments Q, S and T is not wide enough to show significance.

## SIGNIFICANCE OF THE RESULTS

Willcox [1930] maintains that crops not only require the amounts of nitrogen or other minerals that are taken to build up the tonnage of the crop but these must be present in the soil to create a sort of pressure (*satiation pressure*) that forces the vegetative cells to go through their functions. From this it readily follows that manurial value of those fertilizers, as are resorbed immediately, is much higher than those which do not readily do so. Further indirect evidence to support this view has been given by Truog [1928] who describes solid phase feeding by plants in part to make up defficiency left over in the liquid phase feeding of the crop. Solid phase, feeding applies to such manures as are not directly absorbed and have residual effect. With these therefore, satiation pressure in the soil always remains effective and the cells remain more active than would otherwise be the case with manures that are quickly absorbed. In the second set of experiments organic manure (castor cake) that leaves its residual effect and therefore meets the requirements of satiation pressure and solid phase feeding, increases the efficiency of water requirements compared to the artificials.

Ayres [1937] has shown that maximum requirements of the crop for the mineral matter are in the early stages of growth of the crop. The experimental evidence from both these sets of experiments supports this contention. It seems to be the reason why a full dose applied at planting is more beneficial than the two half doses. A full dose at planting by creating higher satiation pressure in early stages is likely to induce better development of plants which ultimately results in higher efficiency of water requirements. The results of these experiments if confirmed by field experiments will have considerable agronomic value in saving the cost involved in making the second application of manure to the sugarcane crop.

The significance of boron in agriculture has been dealt with by Dennis and O'Brien (1937) in a monograph. Russel [1937] from the evidence of Terilokowski and Nowicki [1933] points out that '..........quantities in excess of the very small amounts needed by plants are harmful' and this probably explains why the plants did not show increased efficiency of water requirements. Since the quantities suggested are too small it may not be possible to work out the effect so clearly unless the experiments are specially laid out for the purpose.

## SUMMARY

The results of water requirements studies obtained from two sets of experiments reported above may be summarized as under:

(1) The complete manurial dose, whether it belonged to organic or inorganic schedule, applied all at the time of planting made the plants more economical in the use of water than the cases in which this manure was applied in two half-doses, that is half applied at planting and the remaining half at earthing up or in which no manure was applied.

(2) The application of Niciphos II was less economical from the point of view of water expenditure than an equivalent dose of castor cake.

(3) The application of potash reduced the water expenditure per unit of dry matter produced.

(4) The application of boron did not compare favourably with the in standard schedule (40 lb. N+50 lb. $P_2O_5$) though the plants showed better results than the ones in no manure series (control) which were least economical from water expenditure point of view.

(5) The application of fertilizers in general gave statistically significant increase over no manure in the relative efficiency of water requirements as compared to non-manurial treatments.

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# THE QUALITY OF THE DRAIN, RIVER AND CANAL WATERS OF THE PUNJAB

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(With six text figures)

With the development of canal irrigation and the consequent rise of water-table in the Punjab has arisen the question of drainage. The two doabs which have been primarily affected by water-logging are Chaj Doab and Rechna Doab. The Chaj Doab lies between the rivers Jhelum and Chenab, and the Rechna Doab lies between the Chenab and the Ravi.

Figs. 1 and 2 show the main, the branch and the subsidiary drains of the Chaj and Rechna Doabs respectively.

## The chaj doab

The main drainage systems of the Chaj Doab are the following :

1 Wan Drainage System

2 Raniwah Drainage System

3 Mona Drain

4 Lower Rani-wah Drain

1. *The Wan Drainage system*

This is a net work of several small drains forming a more or less complete circle which drains the area between the Chenab escape on the north-east side and the Southern Branch, Lower Jhelum Canal on the north-western portion. The total catchment area is equal to 28 square miles.

2. *The Raniwah Drainage System*

Towards the Jhelum side, the main natural drainage starts north-east of the town of Miani and travelling parallel to the river, discharges into it.

3. *The Mona Drain*

It starts from the right side of the Main Line, Lower Jhelum Canal. It pours its water into the Sulki Creek which in turn joins the river Jhelum. The total catchment area of the Mona Drainage System is approximately 476 square miles.

4. *The Lower Rani-wah Drain*

The Lower Rani-wah Drain has its beginning in the Bhek Main Drain which starts near R.D. 65,000 of the Sulki Branch, opposite the point where the Mona Drain enters the Sulki Creek. The total catchment area of the Lower Rani-wah Drain is approximately 301 square miles

## The rechna doab

The system of drainage that had developed to any large extent in this Doab was the Vagh Nallah. The total catchment area of this system is approximately 450 square miles.

As the programme for the construction of drains developed, the question of disposal of the drainage waters usefully became essential. One method that readily suggested itself was to mix the drain waters with the canal waters. This required a check on the quality of the mixed water so that the total salts do not exceed the suitability limit.



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Fig. 1. The main, the branch, the subsidiary drains of the Chaj Doab

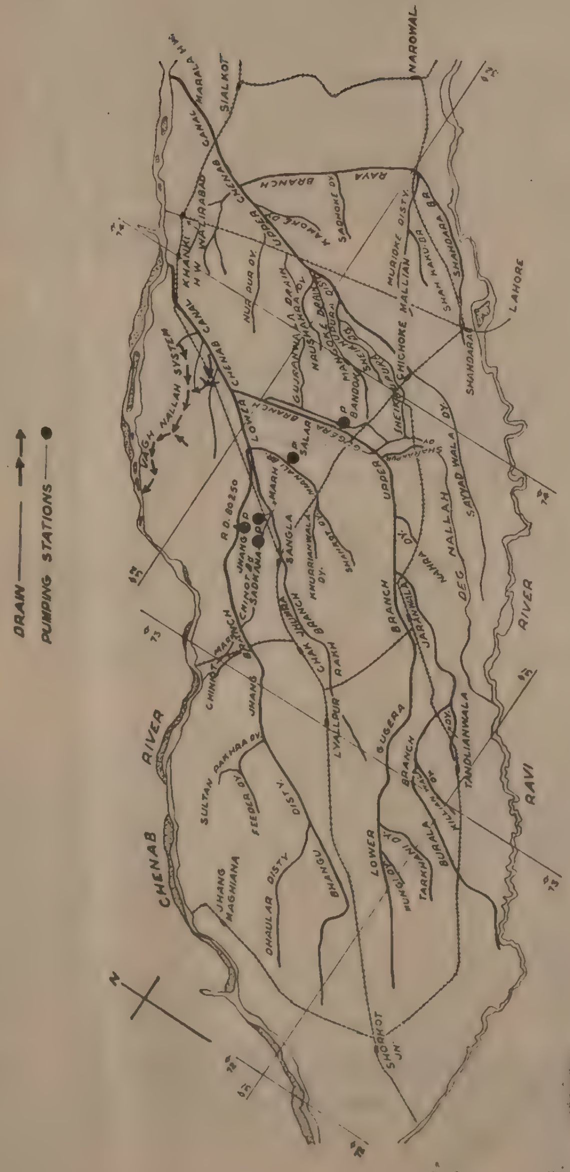


Fig. 2. The main drains & the pumping stations of the Rechna Doab

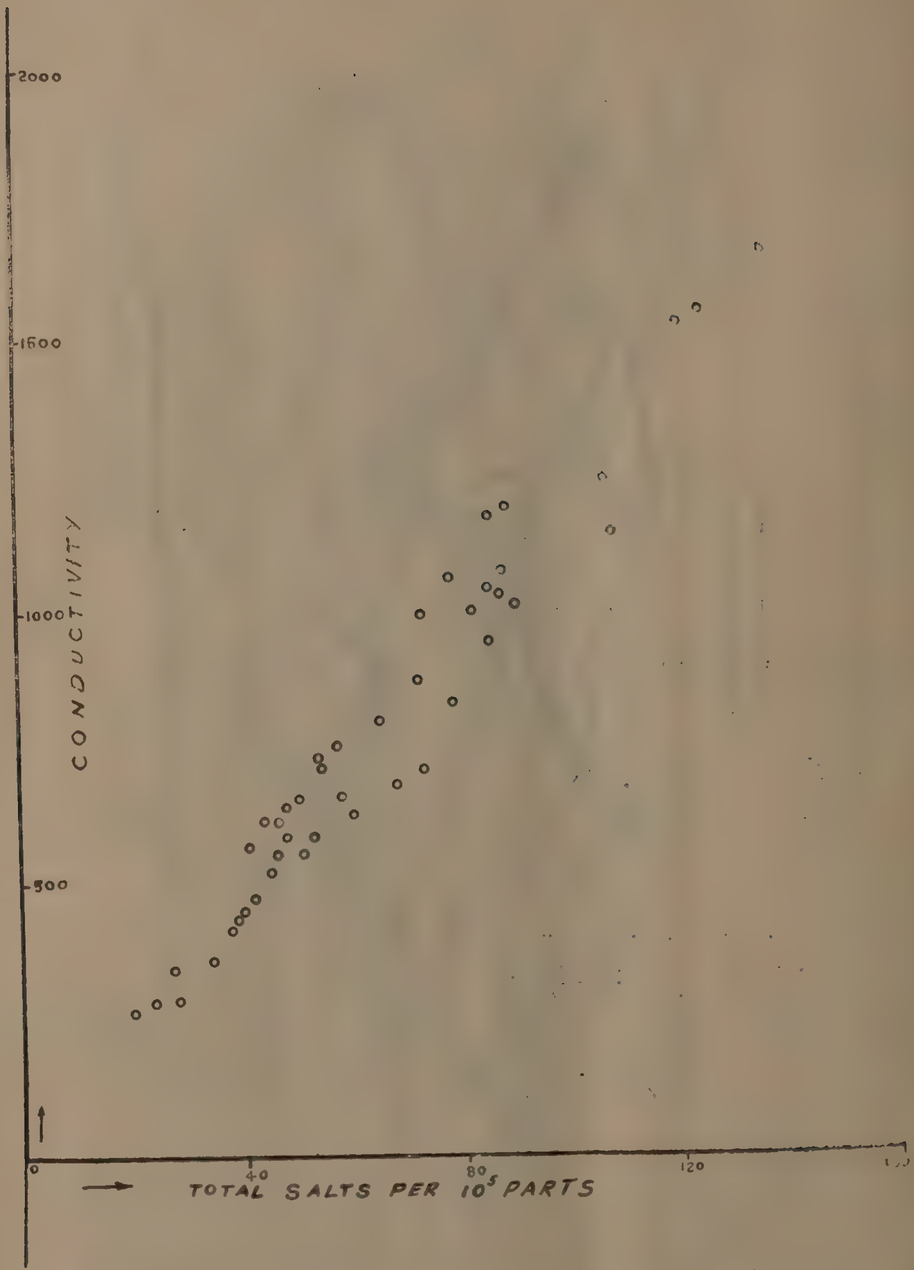


FIG. 3. The relation between conductivity and total salts of the drain waters

## EXPERIMENTAL

A regular analysis of the waters of the major drains was started in 1933 with the following points in view :

*a*. Is the water fit for irrigation ?

*b*. Are there any changes in the salt content of the water with the passage of years ?

*c*. How far the drains are responsible for removing the salts from their catchment areas ?

The waters were analyzed in the laboratory according to the usual method of analysis, and the results interpreted *vide* Taylor, Puri and Asghar [1935].

The standard for the suitability of water for irrigation purposes at present is that water containing 60 parts of salts per 100,000 parts of water is fit for irrigation, but if the water contains 60 to 120 parts of salts, the salt index should be determined according to the equation given below :

Salt index=(Total sodium—24·5)—(Total calcium—calcium in calcium carbonate) × 4·85.

The salt index is negative for waters fit for irrigation and positive for waters unfit for irrigation. The upper limit beyond which the water is generally declared to be unfit for irrigation purposes is 120 parts of salts per hundred thousand parts of water.

## DISCUSSION OF RESULTS

(a) *Relation between conductivity and salt content of the drain waters*

Examination of water samples from various drains has been in hand for many years. The results of analysis of water (having total salts less than 160·0 parts per 100,000) are plotted in Fig. 3. The correlation of total salts with conductivity is positive and is 0·90 which is highly significant. The regression equation is $y=0{\cdot}08\ x+3{\cdot}0$ where x = conductivity and $y$=total salts per 100,000 parts. The actual and the calculated values for a few drains are given in Table I. The agreement is excellent.

TABLE I

*The agreement between the experimental and the calculated values of total salts of the drain waters*

| Serial No. | Name and site of the drain | Conductivity | Total Salts per 100,000 parts | |
|---|---|---|---|---|
| | | | Experi-mental | Calculated |
| 1 | Wan drain at R.D.O. | 610 | 45·6 | 51·8 |
| 2 | Wan drain (Pumping station) | 565 | 40·9 | 48·2 |
| 3 | Wan drain at R.D. 37,500 | 637 | 48·0 | 59·0 |
| 4 | Mixture of Wan drain and Khadir Branch | 260 | 19·6 | 23·8 |
| 5 | Lower Rani-wah drain at R.D. 42,000 | 9,162 | 722·0 | 737·0 |
| 6 | Lower Rani-wah drain at R.D. 238,500 | 6,351 | 467·5 | 511·0 |
| 7 | Lower Rani-wah drain at R.D. 228,364 | 7,694 | 619·5 | 618·5 |
| 8 | Mona drain at R.D. 13,200/14,000 | 991 | 743·8 | 795·8 |
| 9 | Mona drain at R.D. 135,500 | 995 | 72·7 | 82·6 |
| 10 | Mona drain at R.D. 327,500 | 1,095 | 78·0 | 87·7 |
| 11 | Mona drain at Sulki creek | 1,171 | 84·9 | 96·7 |
| 12 | Tail Jhattanwali drain | 443 | 40·1 | 38·4 |
| 13 | Tail Kalerwali drain | 625 | 60·4 | 53·0 |
| 14 | Tail Shari drain | 353 | 34·0 | 31·2 |
| 15 | Tail Gajargola drain | 750 | 57·5 | 63·0 |
| 16 | Tail Said Nagar drain | 1,000 | 32·2 | 83·0 |
| 17 | Tail Bucha drain | 1,098 | 107·5 | 90·8 |
| 18 | Head Ahmed Pur Wagh drain | 468 | 41·5 | 40·4 |
| 19 | Ahmedpur Wagh drain at R.D. 30,000 | 582 | 52·95 | 49·6 |
| 20 | Tail Ahmedpur Wagh drain | 681 | 53·6 | 57·5 |
| 21 | Tail Sagar Branch drain | 344 | 27·3 | 30·5 |
| 22 | Tail Ramgarh Nawan drain | 610 | 44·0 | 51·8 |
| 23 | Tail Hafizabad drain | 1,034 | 86·4 | 85·7 |

TABLE I—*contd.*

*The agreement between the experimental and the calculated values of total salts of the drain waters*—contd.

| Serial No. | Name and site of the drain | Conductivity | Total Salts per 100,000 parts | |
|---|---|---|---|---|
| | | | Experimental | Calculated |
| 24 | Tail Chammi drain | 1,668 | 135·6 | 136·4 |
| 25 | Tail Karyala drain | 710 | 54·0 | 59·8 |
| 26 | Tail Ratteki Drain | 410 | 30·0 | 35·8 |
| 27 | Tail Thatta Raika drain | 430 | 39·0 | 37·4 |
| 28 | Ahmedpur Kot Nikka drain R.D. at 50,000 | 710 | 73·2 | 59·8 |
| 29 | Ahmedpur Kot Nikka drain at R.D. 17,000 | 684 | 67·5 | 57·7 |
| 30 | Head Jurian Kassoki drain | 286 | 27·6 | 25·9 |
| 31 | Tail Jurian Kassoki drain | 517 | 44·8 | 41·4 |
| 32 | Salar drain at R.D. 30,000 | 578 | 48·1 | 49·2 |
| 33 | Marh Salar drain at R.D. 79,000 | 552 | 46·3 | 47·2 |
| 34 | Melowana drain at R.D. 2,000 | 1,013 | 90·3 | 89·0 |
| 35 | Sukheki drain at R.D. 2,000 | 3,008 | 225·6 | 243·6 |
| 36 | Sukheki drain at R.D. 1,000/3,000 | 2,742 | 270·0 | 222·4 |
| 37 | Vanir drain at R.D. 1,000 | 2,430 | 181·9 | 197·4 |
| 38 | Dabora drain at R.D. 100 | 3,688 | 314·6 | 298·0 |
| 39 | Marh Chiniot at R.D. 165,000 | 1,075 | 87·4 | 89·0 |
| 40 | Marh Chiniot Main drain at R.D. 125,000 | 1,513 | 119·8 | 124·0 |
| 41 | Marh Chiniot at R.D. 16,000 | 1,554 | 124·3 | 127·3 |
| 42 | Tail Kutreka drain | 2,494 | 205·6 | 202·5 |
| 43 | Rechna seepage drain at R.D. 5,000 | 283 | 24·1 | 25·6 |
| 44 | Rechna Seepage drain at R.D. 30,000 | 555 | 50·8 | 47·4 |
| 45 | Rechna seepage drain at R.D. 56,000 | 997 | 84·6 | 82·8 |
| 46 | Gujranwala drain at R.D. 1,000 | 652 | 58·0 | 55·2 |
| 47 | Tail Mangoki drain | 877 | 72·4 | 73·2 |
| 48 | Sheikhupura drain at R.D. 2,000 | 1,240 | 96·5 | 102·2 |
| 49 | Tail Dhilwan drain | 833 | 77·9 | 69·6 |
| 50 | Tail Rechna outfall drain | 946 | 84·6 | 78·7 |
| 51 | Tail Jagatan drain | 650 | 50·0 | 55·0 |
| 52 | Tail Chakhni drain | 800 | 69·6 | 67·0 |

(b) *Suitability of water for irrigation purposes*

The water of the Wan drain is generally fit for irrigation purposes. It has been noticed that sometimes the salt content rises above the safe limit of 60 parts per 100,000 but then the mixed water of the drains and the Khadir branch is suitable. The waters of the lower Rani-wah drains are unfit for irrigation. Where the total salt content exceeds the safe limit of suitability, it is to be mixed with canal water in order to bring down the total salts within the permissible limits.

The results of analysis of the canal waters are given in Table II.

TABLE II

*Composition and concentration of salts in the waters of the Punjab rivers and canals*

| Sampling site | Salt Contents Calcium | | (Parts per 100,000) Sodium | | | Total | Conductivity |
|---|---|---|---|---|---|---|---|
| | Sulphate | Bicarbonate | Sulphate | Bicarbonate | Chloride | | |
| Western Jumna Canal near Abdullapur | 4·8 | 10·0 | 1·9 | .. | 1·8 | 18·5 | 260 |
| River Sutlej near Pillaur | 3·4 | 16·0 | 3·2 | .. | 2·3 | 24·0 | 325 |
| Sirhind Canal near Doraha | 4·4 | 11·0 | 3·9 | .. | 2·3 | 21·6 | 325 |

TABLE II—*contd.*

*Composition and concentration of salts in the waters of the Punjab rivers and canals*—contd.

| Sampling site | Salt Contents Calcium | | (Parts per 100,000) Sodium | | | Total | Conductivity |
|---|---|---|---|---|---|---|---|
| | Sulphate | Bicarbonate | Sulphate | Bircarbonate | Chloride | | |
| River Beas near Dhilwan | 7·5 | 11·0 | .. | .. | 3·5 | 22·0 | 260 |
| Upper Chenab Canal near Chichoki Mallian (U.C.C.) | .. | 10·0 | 11·4 | 1·1 | 2·9 | 25·4 | 275 |
| Upper Bari Doab Canal near Tibri (U.B.D.C.) | 3·4 | 7·0 | 3·6 | .. | 1·8 | 15·8 | 200 |
| Lower Gugera Branch, Lower Chenab Canal near Jaranwala (L.G.B.) | 8·8 | 11·5 | 1·4 | .. | 2·3 | 24·0 | 250 |
| Lower Jhelum Canal near Ludewala (L.J.C.) | 3·4 | 15·0 | 3·6 | .. | 4·7 | 26·7 | 340 |

The results show that the conductivity and the total salts in parts per $10^5$ parts range between 200 and 340 and 15·8 and 26·7 respectively. The L.J.C. water possesses the highest and the U.B.D.C. the lowest figure. The average ratio of conductivity to the total salts is 11·2. The average calcium/sodium ratio is 3·2. The highest ratio is found in L.G. and the lowest in U.C.C. The U.C.C. contains the highest concentration of sulphate ions, which is all sodium sulphate, and hence shows the lowest calcium/sodium ratio.

Calcium sulphate is present in the water of all the other canals.

All the waters are fit for irrigation.

Taking into consideration the average salt content during the past years, the dilution required to render the unsuitable drain water suitable for irrigation may be done according to Table III.

TABLE III

*The dilution required with the canal water to make the drain water suitable for irrigation purposes*

| Serial No. | Name of the drain | Site | Mean discharge | Total salts in $10^5$ parts | Dilution times to lower the salt content in $10^5$ parts to 30 parts | 60 parts | 100 parts |
|---|---|---|---|---|---|---|---|
| 1 | Lower Rani-wah drain | R.D. 42,000 | .. | 879·8 | 141·7 | 22·8 | 10·3 |
| 2 | Mona drain | R.D. 327,000 | .. | 284·8 | 42·5 | 6·2 | 2·4 |
| 3 | Mona drain | R.D. 135,000 | 20·0 | 72·0 | 7·0 | 0·33 | .. |
| 4 | Wan drain | | 10·0 | 48·5 | 3·1 | .. | .. |
| 5 | Sukheki drain | R.D. 3,000 | 2·9 | 288·8 | 43·1 | 6·4 | 2·5 |
| 6 | Chiniot drain | R.D. 181,000 | 41·0 | 80·5 | 8·4 | 0·57 | .. |
| 7 | Chhami drain | R.D. 1,000 | 4·5 | 134·2 | 17·4 | 2·1 | 0·45 |

(c) *Changes in salt content with the passage of years*

The rate of increase in the total salts of some of the drain waters with the passage of years is incorporated in Table IV. The salt content of lower Rani-wah drain is increasing at the rate of 71·5 parts per $10^5$ parts and 29·8 parts per $10^5$ parts per annum at R.D. 42,000 and R.D. 238,500/228,364 respectively. The other drains do not exhibit any appreciable change in the salt content.

TABLE IV

*The rate of increase of decrease in the salt content of some of the drains per year*

| Serial No. | Name and site of the drain | Number of years on which rate is calculated | Rate of increase or decrease in salt content per year |
|---|---|---|---|
| 1 | Wan drain at R.D. 37,500 | 11 | +2·3 |
| 2 | Wan drain at wan minor crossing | 13 | +2·3 |
| 3 | Mixture of wan drain and Khadir branch | 14 | +0·34 |
| 4 | Sulki creek | 13 | +3·5 |
| 5 | Mona drain at R.D. 13,200/1,400 | 13 | −1·5 |
| 6 | Mona drain at R.D. 135,500 | 12 | +2·0 |
| 7 | Mona drain at R.D. 327,500 | 12 | +0·84 |
| 8 | Lower Rani-Wah at R.D. 42,000 | 8 | +71·5 |
| 9 | Lower Rani-Wah at R.D. 238,500/228,364 | 8 | +29·8 |

(d) *Amount of salt removed by the drains per year*

The drains perform double function. They not only remove the surface water, but also remove the salts from the soil. Table V (1940) gives the amount of salts removed by the drains per year. Though the salts removed by the drains every year are thousands of tons, yet the removal when taken into consideration with the total quantity of salts present in the catchment area of the drains is insignificantly small. The following example will make the point clear.

TABLE V

*The total salts removed by some of the drains per year*

| Serial No. | Name and site of the drain | Average discharge in cusecs | Average total salts per $10^5$ parts | Total salts removed per year (in tons) |
|---|---|---|---|---|
| 1 | Lower Rani-wah at R.D. 42,000 | 16·2 | 722·0 | $10^5 \times 1{\cdot}03$ |
| 2 | Mona drain at R.D. 13,200/14,000 | 14·3 | 74·4 | $10^3 \times 9{\cdot}4$ |
| 3 | Wagh drain at R.D. 30,000 Ahmadpur | 97·6 | 52·95 | $10^4 \times 4{\cdot}55$ |
| 4 | Mona drain at R.D. 327,500 | 44·0 | 78·0 | $10^4 \times 3{\cdot}02$ |
| 5 | Ahmedpur Kot Nika drain at R.D. 50,000 | 32·5 | 73·20 | $10^4 \times 2{\cdot}01$ |
| 6 | Head Jurian Kassoke drain | 3·6 | 27·6 | $10^3 \times 0{\cdot}87$ |
| 7 | Marh Salar drain at R.D. 79,000 | 14·0 | 46·3 | $10^3 \times 5{\cdot}7$ |
| 8 | Sukheki drain at R.D. 2,000 | 2·8 | 225·6 | $10^3 \times 5{\cdot}6$ |
| 9 | Marh chiniot drain at R.D. 16,000 | 50·1 | 124·3 | $10^4 \times 5{\cdot}5$ |
| 10 | Gujranwala drain at R.D. 1,000 | 11·4 | 58·0 | $10^3 \times 5{\cdot}8$ |
| 11 | Tail Shorey drain | 47·5 | 34·0 | $10^4 \times 1{\cdot}4$ |
| 12 | Tail Mangoki drain | 4·0 | 72·4 | $10^3 \times 2{\cdot}6$ |
| 13 | Tail Jhatanwali drain | 21·5 | 40·1 | $10^3 \times 7{\cdot}6$ |

Assuming that the average salt content of the catchment area of the Mona drain at R.D. 327,500 is 0·40 per cent, it will be necessary to reduce it to 0·20 per cent so that the soil comes within the permissible limits of salt content. The total catchment area of the drain is about 476 sq. miles. The depth of the soil crust may be taken as 8 ft. and the weight of one cubic foot of soil as 100 lb.

$$\text{Total wt. of the soil} = \frac{476 \times 1760 \times 1760 \times 3 \times 3 \times 8 \times 100}{2240} \text{ tons} = 47{\cdot}22 \times 10^8 \text{ tons}$$

$$\text{Total wt. of the salts to be removed from the above soil} = \frac{47{\cdot}22 \times 10^8 \times 0{\cdot}2}{100} \text{ tons} = 9{\cdot}44 \times 10^6 \text{ tons}$$

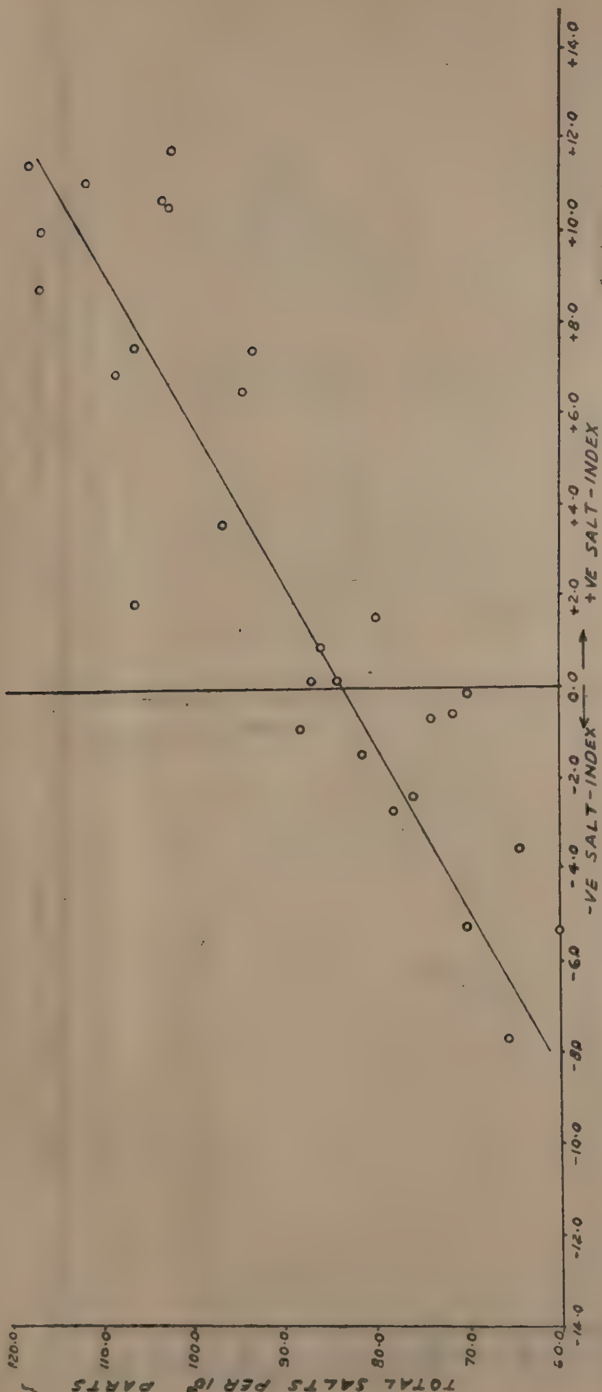


Fig. 4. Relation between salt index and total salts of the dbain waters

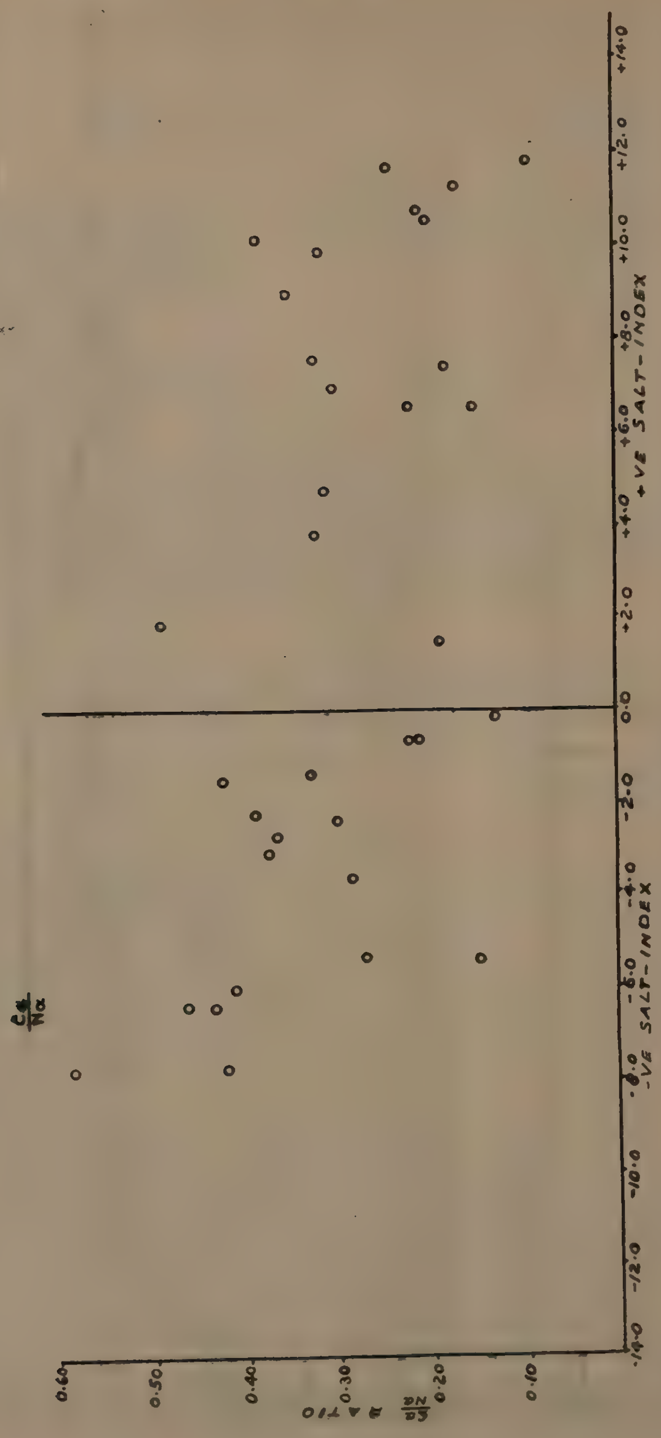


FIG. 5. Relation between salt index and Ca Na ratio of the drain waters

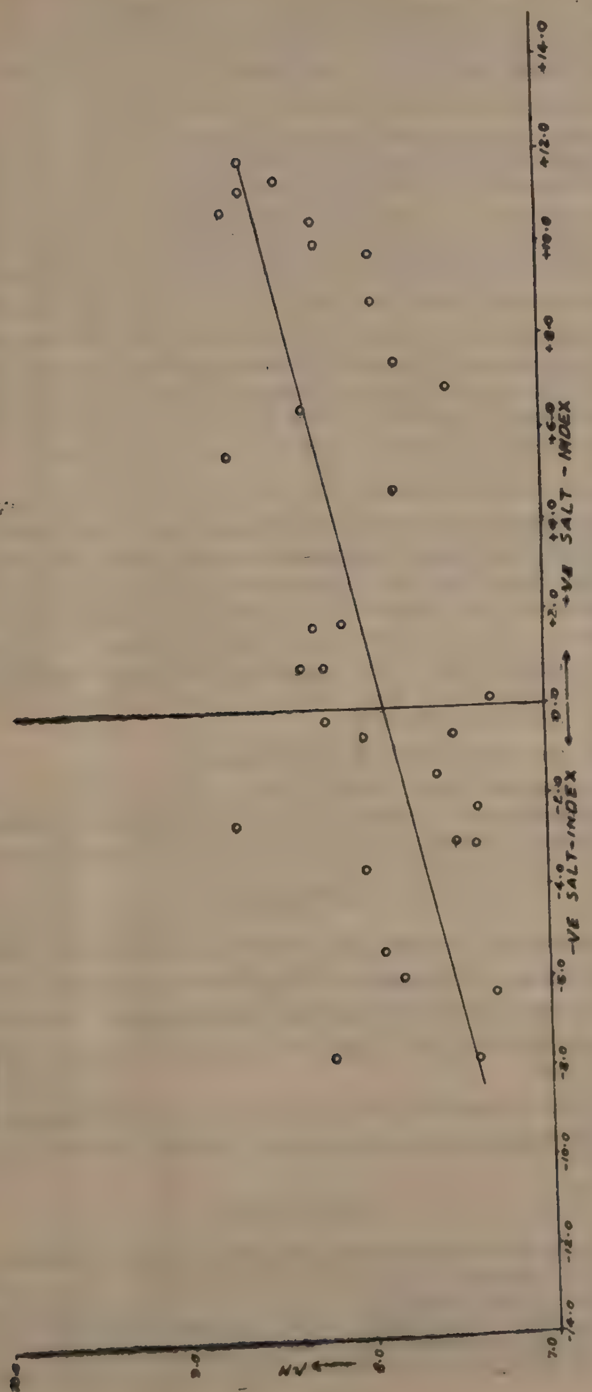


FIG. 6. Relation between salt index and pH

The average annual removal of the salts in the Mona drain is $10^4 \times 3{\cdot}02$ tons (*vide* Table V). Therefore the number of years required to remove $9{\cdot}44 \times 10^6$ tons of salt $= 9{\cdot}44 \times 10^6 / 3{\cdot}02 \times 10^4$ about 312 years. Thus the reduction in salt content as affected by the drain is not appreciable.

(e) *Relation between salt index, total salts, calcium/sodium ratio, and pH value*

(i) Fig. 4 shows the relation between the salt index and the total salt content of the drains. The graph signifies that the total salt content is approximately a function of the salt index. For the positive salt index the salts increase with the increase in the salt index, while for the negative salt index the salts decrease with the increase in the salt index. Thus the drain waters unfit for irrigation contain mostly sodium salts, and the quantity of calcium decreases proportionately with the increase in total salts. The waters with negative salt index behave differently. The correlation of total salts with salt index is 0·94 and positive which is highly significant.

(ii) *Relation between the salt index and calcium/sodium ratio of the drain waters*

Fig. 5 shows the relation between the calcium/sodium ratio and salt index of the waters. Though there is a scatter of the points yet it is pointed out that the calcium sodium ratio increases with the increase in the negative salt index. The correlation of calcium/sodium ratio with salt index is 0·46 and negative. It shows that high Ca/Na ratio is associated with low salt index. Water containing high Ca/Na ratio possesses a highly negative salt index, and vice versa.

(iii) *Relation between the salt index and pH value*

Fig. 6 represents the relation between the positive and negative salt index and *p*H value.

The higher the positive salt index, the higher is the *p*H value. It is vice versa in the case of waters of negative salt index. But the agreement is not well marked. The results signify the importance of the introduction of calcium ions in making the waters fit for irrigation. It has been noticed that calcium permutite [1947] and calcium sulphate can be used for converting the positive salt index into negative one. This conversion would automatically change the unfit water into a fit one. The correlation of salt index with *p*H value is 0·66 and positive. It means high salt index is associated with high *p*H value.

(f) *Aquatic flora of the drains in relation to their salt content*

The drains are infested with many kinds of flora. But it has been observed that with the increase in total salts *Potamogenton pectinatus* increase in number and *Hydrilla* [1916] decrease in number. In drains of low salt content *Vallisneria* and *Hydrilla* predominate.

## Summary


1. There is a close relationship between the conductivity and the total salt content of the drains.
2. The drain waters are not very alkaline. The *p*H values range between 7·25 and 8·75.
3. The drains are removing several thousand tons of salts per year. But the process is very slow.
4. Except the lower Rani-wah drain, there is no significant change in the salt content of the drain waters per year.
5. Salt index is the real determining factor in the quality of the drain water.
6. The occurrence of *Potamogenton pectinatus* is an indicator of the high salt content in the drain water.


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# A PRELIMINARY NOTE ON THE ESSENTIALOIL-BEARING PLANTS GROWING IN KASHMIR—PART III

By K. L. Handa, L. D. Kapoor and I. C. Chopra, Drug Research Laboratory, Kashmir State

(Received for publication on 7 October 1947)

In continuation of the work [Chopra *et al.*, 1946 and 1947] on the study of the essential oil-bearing plants of Jammu and Kashmir a few more plants reputed for their aromatic properties were collected during botanical tours in the Kashmir valley.

The study of these plants has revealed that some of these yield a fair percentage of essential oil which can be economically exploited for medicinal and cosmetic purposes.

The studied plants are noted below.

## 1. *Xanthoxylum alatum Roxb.* (Vern. *Timbru*)

The plant is usually a shrub but at times attains the height up to 20 ft. It grows along the foot of the Himalaya from the Indus eastwards ascending to an altitude of 5,000 ft. usually in rather hot, dry places [Parker 1924]. In Kashmir the plant is common in the Jhelum valley below Uri (25 miles from the valley).

Every part of the plant possesses a peculiar aromatic pungent smell. Walking sticks and clubs are made from its stems and fragrant twigs are used as tooth brushes. In the indigenous system the fruits and bark are used in fevers, dyspepsia and cholera. [Chopra, 1933.]

For the study of the essential oil the fruit of this plant was obtained from Muzaffarabad district. On steam distillation a pale yellow oil with a peculiar odour was obtained with the following characteristics which have been compared with those of the foreign oil [Gildemiester and Hoffmann, 1922].

| | *Local oil* | *Foreign oil* |
|---|---|---|
| Yield of oil from dry fruits | 2·1 per cent | 3 per cent |
| Sp. gravity | 1·025 at 15°C. | 0·8653 at 15°C. |
| Refractive index | 1·475 at 20°C. | 1·48131 at 20°C. |

## 2. *Aegle marmelos* Corr. (Vern. *Bael*)

The tree is indigenous to India and is found wild all over the sub-Himalayan forests, in Bengal, south India and Burma. It is also cultivated at various places for the alleged medicinal properties of the fruit [Collett, 1921]. It is very common in the lower forests of Jammu Province. The unripe fruit is regarded as an astringent, digestive, stomachic and is said to be an excellent remedy for diarrhoea and dysentery [Chopra, 1933].

Both the fresh and dry fruits and leaves procured from Jammu were steam distilled. The yield of the essential oil from the fruits was rather poor. The leaves yielded quite a good quantity of the oil which has the following properties :

| | |
|---|---|
| Yield of oil from fresh leaves | 0·23 per cent |
| Yield of oil from dry leaves | 0·54 per cent |
| Yield of oil from fresh fruit | Traces |
| Sp. gravity | 0·807 at 15°C. |
| Refractive index | 1·448 at 20°C. |

## 3. *Juniper berries*

Juniper berries and the oil extracted from them are very ancient remedies and were used for digestive and diuretic purposes. Juniper oil in the commerce is much used for preparing the well known beverage ' gin ' which owes its characteristic flavour to Juniper [Chopra, 1933]. There are three species of Juniper which grow in Kashmir : *Juniperus communis*, *J. macropoda* and *J. recurva*. Out of these species *Juniperus recurva* is rather scarce. Effort is being made to procure its berries and the results will be communicated in due course.

*Juniperus communis* Linn. (Vern. *Vither*). It is an ever-green shrub which grows at high altitudes from 9,000 to 14,000 ft. in the inner dry ranges of mountains. The ripe berries of the plant procured from the Sindh valley were steam distilled. The properties of the oil obtained from the berries are given below and are compared with those of the foreign oil [Parry, 1925] :

| | *Local oil* | *Foreign oil* |
|---|---|---|
| Yield of oil from dry berries | 0·77 per cent | 0·5 to 1·05 per cent |
| Sp. gravity | 0·9388 at 15°C. | 0·865 to 0·890 at 15°C. |
| Refractive index | 1·488 at 20°C. | 1·475 to 1·488 at 20°C. |

*Juniperus macropoda* Boiss (Vern. *Padam*). It is a medium sized tree which grows in inner dry ranges of the Himalayas at altitudes of 8,500 to 14,000 ft. It is very common in the Gurez valley. The wood of the tree is much used for pencil making. The dry berries of the plant procured from Gurez valley yielded a sweet smelling oil on steam distillation which had the following properties :

| | |
|---|---|
| Yield of oil from dry berries | 3·3 per cent |
| Sp. gravity | 0·8571 at 15°C. |
| Refractive index | 1·473 at 20°C. |

4. *Ferula Jaeschkeana* Vatke (Vern. *Hing*)—

A number of *Ferula* species grow wild in the Kashmir valley and in the bordering hills. The important species are *Ferula narthex*, *F. thomsoni* and *F. jaeschkeana*.

The authentic specimens of the gum resin, asafoetida, which oozes out of incision on the roots of the plant could not be made available and only the roots and dry fruits of *F. jaeschkeana*, which could be procured, were studied. The gum resin (asafoetida) will be studied and the results communicated later on.

*F. jaeschkeana* which is an erect perennial herb grows commonly on the slopes of mountains at altitudes of 6,000 to 12,000 ft. above the sea level. It is reported to be common in Baluchistan. In Kashmir it grows commonly in the Gulmarg, Verinag, Gurez and Kamri ranges. The gum resin (asafoetida) is used locally as a condiment and in the treatment of flatulence [Bamber, 1916].

The roots and mature fruits of the plants were collected from Verinag and Gulmarg ranges and the essential oil distilled from these, had the following properties :

| | |
|---|---|
| Yield of oil from dry roots | 1·2 per cent |
| Sp. gravity | 1·149 at 15°C. |
| Refractive index | 1·453 at 20°C. |
| Yield of oil from dry fruits | 3·8 per cent |
| Specific gravity | 0·857 at 15°C. |
| Refractive index | 1·464 at 20°C. |

5. *Archangelica officinalis* (Var. *Himalaica*)—

It is a large perennial erect herb assuming the size of a small tree. It is commonly found in Kashmir near the water channels at altitudes from 8,000 to 13,000 ft. especially in the hills near Gulmarg and Gurez.

The fruit and the roots of the plant are reputed for their aromatic properties. In Europe the plant *A. officinalis* is official and its essential oil is used as a flavouring agent in confectionary and in liquors [Bamber, 1916].

The fruits and roots were collected from Gulmarg and on steam distillation the oil yielded had the following properties :

| | |
|---|---|
| Yield of oil from dry roots | 0·8 per cent |
| Sp. gravity | 0·8922 at 15°C. |
| Refractive index | 1·4478 at 20°C. |
| Yield of oil from dry fruits | 3·8 per cent |
| Sp. gravity | 0·887 at 15°C. |
| Refractive index | 1·464 at 20°C. |

6. *Carum carui* Linn., Caraway (Vern. *Zira*)—

Caraway consists of the dried ripe fruits of *Carum carui* an erect biennial herb indigenous to and cultivated in North and Central Europe, chiefly in Holand and in Central Asia. In India it is cultivated as a summer crop in the hills of Baltistan, Kashmir, Kamaon, Garhwal, etc. at an altitude of 9,000 to 12,000 ft. In Kashmir the plant commonly occurs in Astore, Drawa, Gurez, Skardu and it is also cultivated in the valley. The plant is cut when the fruit is ripe, which is then separated by thrashing. It is largely used in both the Indian and western systems of medicine as stomachic and carminative. Caraway oil is used as carminative. Caraway oil is also used for flavouring wines and scenting soaps in perfumery [Chopra, 1933].

For the distillation of the essential oil caraway seeds growing in Skardu, Gurez and Baghbanpura were procured and the properties of the oil thus obtained were studied. These are compared with the standards laid down in *British Pharmaceutical Codex*, 1934 :

| Locality | Baghbanpura | Gurez | Skardu | B.P.C. Standard |
|---|---|---|---|---|
| Altitude | 5,500 ft. | 7,900 ft. | 7,700 ft. | .. |
| Yield of oil | 4·3 per cent | 6·8 per cent | 8·5 per cent | 3·5 to 6 per cent |
| Sp. gravity | 0·9095 at 15°C. | 0·8902 at 15°C. | 0·8907 at 15°C. | 0·910 to 0·920 at 15°C. |
| Refractive index | 1·491 at 20°C. | 1·486 at 20°C. | 1·485 at 20°C. | 1·485 to 1·492 at 20°C. |

A perusal of the data shows that the caraway growing in various parts of Kashmir gives pretty good yield of oil which is up to *B.P.* and *B.P.C.* standard.

7. *Prangos pabularia* Lindle (Vern. *Komel*)

It is a large perennial herb which grows at altitudes from 6,000 to 11,000 ft. in Kashmir. The plant is considered to have carminative, diuretic and emmengogue properties. The leaves, flowering tops and dry roots of the plant procured from Pir Panjal range, on steam distillation gave essential oil with the following properties :

| | |
|---|---|
| Yield of oil from dry leaves and flowering tops | 0·65 per cent |
| Yield of oil from dry roots | 1·02 per cent |
| Sp. gravity | 1·129 at 15°C. |
| Refractive index | 1·454 at 20°C. |

8. *Origanum vulgare* Linn. (Wild Marjrom ; Vern. *Satra*)

The plant grows wild commonly in the temperate Himalayas at altitudes from 6,000 to 12,000 ft. In Kashmir it is commonly found from 5,000 to 9,000 ft. in forests in the valley.

It is reported to be eaten at certain places as a pot herb. In the indigenous system of medicine the plant is used as an aromatic, stimulating tonic in diarrhoea, rheumatism and in earache [Chopra, 1933].

The plant was collected from the neighbourhood of Gulmarg and on steam distillation the essential oil had the following characteristics :

| | |
|---|---|
| Yield of oil | 0·76 per cent |
| Sp. gravity | 0·933 at 15°C. |
| Refractive index | 1·477 at 20°C. |

9. *Senecio jacquemontianus* Benth (Vern. *Poshkar*)—

Amongst the many species of *Senecio* which grow wild in abundance in Kashmir the study of *S. jacquemontum* was undertaken for its aromatic properties. It is a large herb and the roots particularly give aromatic odour. The plant grows in the Himalayas at altitudes of 10,000 to 13,000 ft. above the sea level [Bamber, 1916]. In Kashmir it grows wild in Gurez valley.

The roots of the plant were collected during the autumn from Rajdhani (11,000 ft.). On steam-distillation the roots yielded essential oil with the following characteristics :

| | |
|---|---|
| Yield of oil | 1·2 per cent |
| Sp. gravity | 0·9545 at 15°C. |
| Refractive index | 1·483 at 20°C. |

10. *Chaerophyllum villosum* Wall (Vern. *Jangli Gajar*)—

It is a perennial erect herb often found in the temperate Himalayas at altitudes from 5,000 to 12,000 ft. In Kashmir the plants grow abundantly in pine forests and the roots are eaten by the local people as wild carrot.

The whole flowering plant was steam-distilled and the essential oil obtained had the following characteristics :

| | |
|---|---|
| Yield of oil | 0·98 per cent |
| Sp. gravity | 0·9742 at 15°C. |
| Refractive index | 1·463 at 20°C. |

11. *Achillea millefolium* Linn. (Vern. *Momadru, Chopandiga*)—

It is a common plant found in temperate Himalayas at altitudes of 6,000 to 11,000 ft. In Kashmir it is found growing in abundance as a wild weed near the cultivated fields or forest blanks around the valley. The flowering heads of the plant were collected for the distillation of essential oil which was obtained only in traces.

12. *Eryngium caeruleum* Bicb. (Vern. *Dudhali*)—

It is a medium sized erect herb growing common in Kashmir valley at altitudes of 5,000 to 6,000 ft. The root of the plant is taken as an aphrodisiac and nervine tonic. The plant was collected from neighbourhood of Srinagar and on steam-distillation it yielded traces of essential oil.

13. *Anthemis noblis* Linn. (Vern. *Babune-ke-Phul*)—

It is a small herb growing wild and is also cultivated in the temperate Himalayas for the medicinal properties recognized in the Tibbi system of medicine as stimulant and tonic [Chopra, 1933]. The flowers were collected locally but on steam distillation only traces were found.

The physical properties of the oils from the three plants mentioned above could not be studied as sufficient amounts could not be obtained by distillation.

## Acknowledgement

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# A NEW SEEDLING DISEASE OF BRINJALS

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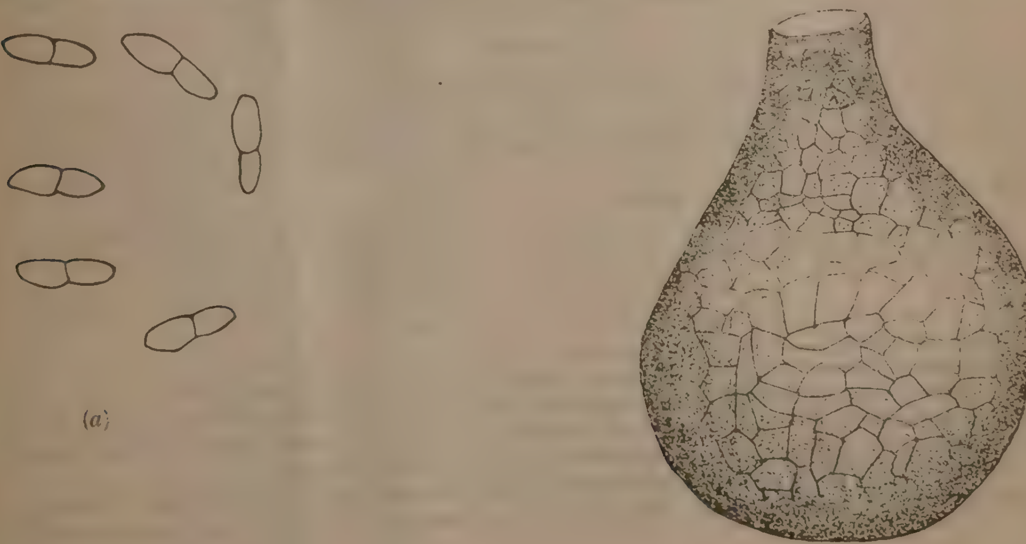
(Received for publication on 20 November 1946)

(With two text figures)

A DISEASE causing leaf spots in brinjal seedlings was found in the Departmental Seedling Nursery at Jessore (Bengal) in November, 1945. The spots are small, brown in colour, and somewhat angular in the beginning. They enlarge to become circular or elliptical or irregularly elliptical and possess a well defined margin. In the older spots the central region becomes papery and transluscent. Sometimes shot-holes are also formed. The spots on enlargement show a marked tendency to be confined between the principal lateral veins of the leaf lamine, with the result that irregular spots are formed when their margins run parallel to the veins.

## Causal organism

The fungus associated with the above symptoms on brinjal seedlings is an *Ascochyta* species producing numerous, half immersed, brown, sub-globose, or slightly irregular, papillate pycnidia having distinct ostioles. The wall of the pycnidium is of thin brown parenchyma with dark walls. The spores are at first continuous, ellipsoid or cylindrical, with rounded or blunt ends. The mature spore develops, a single septum in the middle and is stout, cylindrical, or oblong, with rounded or blunt ends. There is a waist-like constriction of the side walls where these come in contact with the median septum. Two guttulations are also seen in each of the two cells of the spore. The unseptate spores measure $7{\cdot}8\mu \times 3\mu$. ($4{\cdot}11 \times 3\mu$.), while the septate ones measure $11{\cdot}0\times4\mu$. ($10$-$913 \times 3{\cdot}5$) each. *Taxonomy.* Several species of *Ascochyta* have been recorded on Solanaceae outside India, but not on the cultivated brinjal, *Solanum melongena*. Thus, *A. petuniae* Speg., *A. nicotianae* Pass., *A. physalina* Sacc., *A. daturae* Sacc. [Saccardo, (i)], *A. solanicola* Oud., *A. alkekengi* Mass. [Saccardo, (ii)], *A. dulcamarae* Bubak. [Saccardo, (iii)] and *A. lyco persici* Brun [Grove, 1935] have been reported. No records of *Ascochyta* species on Solanaceae have been made in India [Butler and Bisbey, 1931 ; Uppal *et al.* 1934 ; Mundkur, 1938]. The descriptions of the species reported on Solanaceae are presented in Table I, and compared with that of the fungus on brinjals.



(*a*)

(*b*)

Pycnidia of *Ascochyta Melongenae* n. sp. with pycnospores

(*a*) Pycnidia, × 300

(*b*) Pycnospores × 1800



Q

TABLE I

*Description of* Ascochyta *sp. reported on Solanaceae compared with the fungus on* Solanum melongena *in Bengal*

| Name of fungus | Host | Description |
|---|---|---|
| *Ascochyta petunia* Speg | *Petunia* | Pycnidia—somewhat large, dark coloured ; size, 100-130μ<br>Spores—hyaline, cylindrical, elliptic, median septate, without any constriction ; size, 5-8 × 2μ |
| *A. nicotianae* Pass. | *Nicotiana tabacum* | Spores—ovoid oblong, median septate, hyaline or granulate (no spore measurements) |
| *A. daturae* Sacc. | *Datura stramonium* | Pycnidia—aggregated on the upper side of the leaf, somewhat rounded, 100μ in diameter<br>Spores—cylindrical to oblong, both ends rounded, one septate, size, 7-8 × 3μ |
| *A. physalina* Sacc. | *Physalis Alkekengi* | Pycnidia—immersed on the upper side of the leaf<br>Spores—oblong, cylindrical, constricted, one septate, size, 25-28 × 8μ. 2-4 guttulate |
| *A. solanicola* Oud. | *Solanum nigrum* | Pycnidia—epiphyllous, rare, brown, central pore prominent, diameter 200μ<br>spores—rod-shaped, both ends rounded hyaline, one septate, without constriction ; size, 10-12 × 2·5μ |
| *A. alkekengi* Mass. | *Physalis alkekengi* | Pycnidia—epiphyllous, dot-like, membranous, pale brown, 120-150μ in diameter<br>spores—ovoid, hyaline, continuous, or one septate ; size, 5-10 × 2·5-4μ |
| *A. dulcamerae* Bubak | *Solanum dulcamara* | Pycnidia—immersed in the mesophyll, globose, depressed, 100-150.μ diameter<br>spores—cylindrical, straight or rarely curved, apex rounded, at first continuous later one septate ; size, 7-9 × 2·4μ |
| *A. lycopersici* Brun. | *Lycopersicum esculentum* | Pycnidia—scattered or aggregated on swollen spots, sub-epidermal, erumpent sub-globose, brown to brownish-black, slightly papillate, pierced by a pore or two ; 100-250μ diam, texture. thin parenchymatous, cells clear pale brown darker round the outside<br>spores—ovoid (4-5 × 2·3μ), then sub-cylindrical, hyaline, continuous, then one septate slightly constricted with 2 or no guttules ; size. 9.5 × 3.5. (4·5-15 × 2·5-5μ) issuing in a whitish or flesh coloured tendrils, sporophores, short, simple and filiform |
| *Ascochyta* Sp. | *Solanum melongena* | Pycnidia—numerous, half immersed, brown sub-globose to irregular, papillate and ostiolate, wall cells of thin brown parenchyma with dark walls ; size, 90-217μ.<br>spores—ellisoid cylindrical, with rounded or blunt ends, one septate with constriction two guttulations in each cell ; size, 11.35 × 4μ |

The spore measurements of the species on brinjals are greater than those of other species excepting *A. physalina*, the spores of the last mentioned species being about twice that of any other. The spores are distinguishable from those of *A. solanicola* in being very much stouter in their constrictions at the septal region, and in the presence of guttulations in the cells.

Thus the fungus found on brinjal seedlings in Bengal does not seem to belong to any of the known species of *Ascochyta* on Solanaceae. The name, *A. melongenae* n. sp., is proposed to accommodate it.

## TECHNICAL DESCRIPTION

Pycnidia numerous, half-immersed, globose, sub-globose to slightly irregular, brownish, somewhat papillate and distinctly ostiolate ; pycnidial wall of thin brown parenchymatous cells ; size

90-217 μ, averaging 151 μ in diameter. Spores ellipsoidal with rounded ends, or somewhat cylindrical with rounded or blunt ends; spores on development become one septate, slightly elongated, cylindrical, and have stout walls having waist-like constriction at the septum, and two guttulations in each cell. The unseptate spores measure $7{\cdot}0 \times 3\mu$, with a range of $4{\cdot}11 \times 3\mu$. The septate spores measure $11 \times 4$, with a range of $10{\cdot}13 \times 3{\text -}5\mu{\text -}4{\cdot}98\mu$.

Habit on living leaves of *Solanum melongena* seedlings in Jessore, Bengal; collected by S. Y. Padmanabhan in November, 1945. Type specimen deposited in Herb. Crypt. Ind. Orient, New Delhi.

Pycnidia multa, semi-inserta, globosa, sub-globosa, vel aliquatinus irregularis, brunnea, quadantenus papillata et distincte ostiolata. Latera pycnidiu constituunter ex cellulis parenchymaticis brunneis et tenuis, quarum mensura est 90μ-217μ et generatim circa 151μ. Sporae ellipsoidae cum extremis roundis vel hebetibus. Sporae crescendo fiunt uniseptatae, aliquatenus elongatae, cylindricae, cum crasso latere, circa septum coarctato, cum duabus guttulationibus in singulis cellulis; inseptate sporae sunt $4{\text -}11 \times 3{\text -}5\mu$.

Habitat in folus plantularum *Solani melongenae* in Jessore, Bengal Collegit S. Y. Padmanabhan, mense novemberi, 1945.

Exemplar servatur in Herb. Crypt. Ind. Orient, New Delhi.

## CONTROL

The incidence of the disease in the beds was not severe. It was noticed in its initial stages before it could do much damage. Complete control was effected by plucking out the affected leaves in the beds and spraying the seedlings once with half per cent Bordeaux.

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